JOURNAL

OF THE

SOCIETY OF TELEGRAPH-ENGINEERS AND ELECTRICIANS.

FOUNDED 1871. INCORPORATED 1883.

INCLUDING

ORIGINAL COMMUNICATIONS ON TELEGRAPHY AND ELECTRICAL SCIENCE.

PUBLISHED UNDER THE SUPERVISION OF THE EDITING COMMITTEE,

AND EDITED BY

F. H. WEBB, SECRETARY.

VOL. XV.—1886.

London:

E. AND F. N. SPON, 125, STRAND, W.C.

New York:

35, MURRAY STREET.

1887.

TABLE OF CONTENTS.

VOL. XV.

JOURNAL

OF THE

SOCIETY OF

Telegraph-Engineers and Electricians.

Founded 1871. *Incorporated* 1883.

VOL. XV. 1886. No. 60.

The One Hundred and Fiftieth Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, January 28th, 1886—Mr. C. E. SPAGNOLETTI, M. Inst. C.E., late President, in the Chair.

The minutes of the Annual General Meeting of December 10th, 1885, were read and approved.

The names of new candidates for admission to the Society were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Robert O. Bourne. | Charles H. Sharples.
Hugh Erat Harrison. | H. D. Wilkinson.
O. E. Woodhouse.

From the class of Students to that of Associates—

F. B. O. Hawes. | Eugene J. Moynihan.
Frederick Worsley.

Donations to the Library were announced as having been received from the Colonial Office; the Smithsonian Institution; Professor E. J. Houston; G. M. Whipple, Esq.; A. Andersen, Member; W. Lynd, Associate; C. Mourlon, Foreign Member;

and Willoughby Smith, Past-President; to all of whom the thanks of the meeting were unanimously voted.

The LATE PRESIDENT: Gentlemen,—One of the most pleasing duties in connection with my Presidency devolves upon me this evening. It is that of presenting the premiums which have been awarded by the Council to those who have contributed the best papers during the year ending June last. I may perhaps be allowed to say, in the presence of our younger members, that I consider the honour of receiving a premium from a Society like this is very great indeed; because, if the papers are not really of true value, no premiums are given, and therefore for the author to obtain a premium the paper must necessarily possess considerable merit. The ability and reputation of our Council are well known, and it is a very great honour indeed for the author of a paper to have it selected by such experts as worthy of a premium among the productions that have been brought before the Society. I hope that many of our members will endeavour to gain a premium during the ensuing year, and will contribute papers the excellence of which may be rewarded by the Council of the Society.

The first premium, being "the Society's Premium," value £10, has been awarded to Professor Oliver Lodge for his excellent paper—which brought forth two evenings' discussions—"On the Seat of the Electro-motive Force in a Voltaic Cell." Professor Lodge has chosen Ruskin's Works, and the volumes are here ready to be presented to him, but unfortunately his duties in Liverpool do not permit of his being present to-night, and he has commissioned Professor Perry—who, as you will recollect, crossed steel with him in scientific argument very closely—to receive the books for him; but unfortunately Professor Perry is also lecturing to-night, and cannot attend here until later in the evening, so that the books must remain on the table for the present.

The second, being the "Fahie Premium," value £5, has been awarded to Captain H. R. Sankey, R.E., Associate, for his paper on "Some Experiments in Electrotyping with a Dynamo-electric Machine." You will all recollect that his paper was very interesting, possessed great merit, and was well received by the

Society. Captain Sankey has selected an aneroid barometer, a "Boucher's circular calculating machine," and "Gordon's Electricity," which I now have the pleasure of handing to him.

The next is the "Paris Electrical Exhibition Premium," value £5, awarded to Mr. W. H. Snell, Associate, for his paper, "On the Calculation of Mains for the Distribution of Electricity." I am very sorry, indeed, that on the occasion of that paper being read —which was at an Extraordinary General Meeting devoted to the purpose—I had not the pleasure of being present. It is the only occasion on which I was absent during the past year; but I have read the paper, and can support the selection of the Council in awarding this premium to Mr. Snell, to whom I now have the pleasure to hand these ten volumes of electrical works which he has himself selected.

Now, having performed the routine duties of the office, it only remains for me to express the great pleasure I have in introducing to you my successor, Professor Hughes.

The President, Professor D. E. Hughes, F.R.S., then took the chair.

Professor G. FORBES: Might I ask, before we listen to your interesting remarks, Professor Hughes, for a few moments to perform what is a right and graceful act towards our late President. We know that the success and interest of our meetings depends very much upon the manner in which our President conducts his duties in the chair, and the way in which he introduces the subject and invites discussion upon it. Further, the position of the Society depends a great deal upon the dignity of the chair, in having a President who has a thorough business-like and regular habit; and I may say that we have seldom had a gentleman more suited to that double capacity than Mr. Spagnoletti. He has happily introduced subjects and invited discussions at every meeting at which he has been present, and has conducted the duties of the chair in so methodical and business-like a manner that I am confident of the support of the members present when I propose a hearty vote of thanks to Mr. Spagnoletti for the manner in which he has fulfilled the duties of President.

Mr. W. T. ANSELL: I beg to second the proposition, and can

say that from the bottom of my heart I cordially endorse the sentiments expressed by Professor Forbes in reference to my old friend Mr. Spagnoletti, our late President. I have known him for very many years—from his earliest career in telegraphy—and have been intimately associated with him in very many of the early undertakings which were the pioneers of the magnificent telegraph system which now exists, not only in England, but throughout the world, and, in my old age I am proud to say, in which I have been one of the foremost workers. I am an old man now, and I remember my old friend Sir W. Fothergill Cooke once saying, "We cannot hold a candle to the young ones, there is no mistake about it, and we must give place to younger and better men;" but it has always been to me a matter of great pride that we have been the starters and the pioneers of a science which has grown to the great position in which it now stands throughout the civilised world.

The PRESIDENT: My first duty is an extremely agreeable one, and that is to put to the meeting the vote of thanks which has been proposed by Professor Forbes and seconded by Mr. Ansell.

I am sure that no one can appreciate more than myself the noble way in which Mr. Spagnoletti has fulfilled all the numerous and arduous duties of President of our Society during the past year; and in putting this motion I ask you to carry it unanimously, so that we may all testify our sincere thanks to and highest regard for our past President, Mr. Spagnoletti.

The resolution was unanimously carried.

Mr. C. E. SPAGNOLETTI, in reply, said: I feel exceedingly obliged and gratified at the very kind way in which Professor Forbes has expressed himself, and also to my old friend Mr. Ansell for the way in which he seconded the proposition. As Mr. Ansell said, we have worked together for a very great many years, and it will always afford me much pleasure in looking back to the time when he was my chief. Perhaps it is somewhat due to his attention and training in my early days that I have been qualified for the position in which I am placed to-night. I am obliged to Professor Hughes for his kind expressions, and I assure

you it is most gratifying to me to find that the meeting has so cordially endorsed the proposition.

I would detain you just to say that I feel extremely happy that the Society during my term of office has come a little out of its shell. In regard to electric lighting, a committee of the Society was appointed to consider and bring to the notice of the Government the shortcomings of the regulations in force under the Act of 1882, and, I think, did its work well, giving that branch of the science the support it so much needed. Also, as you know, a committee was formed to consider electrical nomenclature and notation, and that committee has been working hard; but the subject requires much time and great care, and it will not do to hurry its deliberations by pressing for too early results. It is still at work, and I hope that Professor Hughes may be able shortly to report progress. A third committee has been formed to consider the best means by which the standardising of electrical apparatus can be practically carried into effect, the result of which I hope will be of great assistance in remedying many of the defective instruments in existence, and give us a mode of testing and proving instruments that will render reports on tests of real value to all concerned.

I take this opportunity of thanking the Council most sincerely for the kind way in which they supported me during my term of office. Important duties have frequently occupied the Council until late hours on many evenings, but they have always willingly given their time and ability to all questions connected with the Society in the most thorough manner, and my thanks are deeply due to them for their kind support on every occasion. I should also like to express my thanks to our Secretary, Mr. F. H. Webb, who has always, and most willingly, afforded me every assistance in his power, and helped and supported me in every way he could in the office.

The PRESIDENT said it would facilitate the reading of his inaugural address if Mr. Spagnoletti would take the chair *pro tem.*

Mr. Spagnoletti took the chair.

The PRESIDENT then read the following

INAUGURAL ADDRESS.

Before commencing the subject of my address this evening, I desire to express my sincere thanks to the Members of the Society of Telegraph-Engineers and Electricians for the great honour they have conferred on me by electing me as their President, and to assure them that I will do all in my power to aid and promote the interests of our Society, which are those of Applied Science in one of its highest branches.

It is the custom in our Society, that the elected President should open the Session by an address containing a general review of the present state of Electrical Science, or researches in some special branch which may be of interest. I have chosen the latter, as it enables me to present to you some researches which I have not yet published, and I propose to present these in the form of a paper rather than an address, in order to allow our members the opportunity of a full discussion on the subject, which I hope may bring forth many new facts in their possession.

The subject which I have chosen is—

The Self-Induction of an Electric Current in relation to the Nature and Form of its Conductor.

Induced or secondary currents in a near but independent circuit were discovered by Faraday in 1831; and the phenomenon of the self-induction of an electric current in its own wire was observed by Henry in 1832, and traced to its cause in 1834 by Faraday, who proved that on sending a current through a wire a momentary induced current in the opposite direction is evoked in its own wire; also that, on the cessation of the primary current, a second induced or "*extra-current*" is excited in the direction of the primary. The effect is greatly augmented when the wire forms a coil, as we then have in addition the reaction of superposed currents; but the effect exists to a great extent even when the wire forms but a single loop, or a straight wire with the earth forming the returning portion of the loop, as in all telegraph lines.

It has been generally supposed that the nature or the molecular condition of the metal through which the primary current passed exerted no influence upon the extra-currents except that due to its resistance. I have previously pointed out* that for induced currents "the rapidity of discharge has no direct relation with the electrical conductivity of the metal, for copper is much slower than zinc, and they are both superior to iron." This led me to make a study of these extra-currents, for which purpose I constructed a special Induction Bridge, in order to measure both the primary and its extra-currents separately at the instant of action.

Induction Bridge.

This instrument† is a combination of a portion of my "Induction Balance," with a "Wheatstone Bridge." The resistance of the wire is measured and balanced by the bridge; the induced or extra-currents are measured and reduced to zero by an equal opposed induced current from the induction balance.

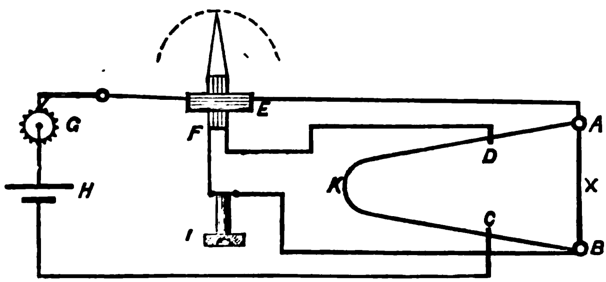


Fig. 1.

The above diagram shows the electrical communications. The bridge consists of a single German silver wire (0·25 mm. diameter, 1 mètre in length, of 4 ohms resistance) running from A to K, returning to B. The wire is stretched and sustained upon two wooden arms articulated at K, by means of which the terminals A B can be more or less separated as desired. The wire to be tested, X, is joined at A and B, thus completing the closed circuit of the bridge.

* "Induction-Currents Balance," *Proc. Roy. Soc.*, vol. xxix., p. 56, 1879; "Molecular Electro-magnetic Induction," *Proc. Roy. Soc.*, March 7, 1881.

† Manufactured by Mr. William Groves, 89, Bolsover Street, Portland Place.

The external communications are shown, A being connected to the primary coil of the sonometer E, and through it to the spring of the interruptor or rheotome G, the interrupting wheel being connected to the battery H, and thence to the bridge at C. The wire from B passes through the telephone I to the secondary coil F, returning to D.

Great care has to be taken in the construction of the bridge, so that it shall be as free as possible from induced or extra-currents; and for this reason we cannot employ or introduce resistance coils. The resistance of the wire X is balanced by sliding the communications D and C. It is evident that if all the arms of this bridge are equal in resistance and inductive capacity, there will be silence on the telephone; but if A B be slightly stronger or weaker in inductive capacity, then we may be able to balance its resistance, but not its induction, as we shall then have a slight or a loud continuous sound due to the differential extra-currents in the arm A B. These are compensated by the introduction in the circuit of the telephone of an equivalent but opposed induced current from the secondary coil of the sonometer F, the degree of angle through which this coil has turned to produce silence being the degree of force of the extra-current. The induction sonometer* consists of two coils only, one of which is smaller and turns freely in the centre of the outside coil. The exterior coil being stationary, the centre coil turns upon an axle by means of a long (20 cm.) arm, or pointer, the point of which moves over a graduated arc or circle. Whenever the axis of the interior coil is perpendicular to the exterior coil no induction takes place, and we have a perfect zero; by turning the interior coil through any degree we have a current proportional to this angle, and in the direction in which it is turned. The value of the induction current for each sonometric degree was $\frac{1}{1500}$ of the primary current which passed through the wire under observation, the latter being variable at will from ·001 to ·250 ampère. There is also a reversing key (not shown in the diagram), in order to place the interruptor on the telephone circuit and close the battery current from H to A; the conditions then

* *Comptes Rendus de l'Académie des Sciences*, Paris, Dec. 30, 1878, and Jan. 20, 1879; *Proc. Roy. Soc.*, vol. xxxi., p. 527, 1881.

being the usual method of testing, except using the telephone in place of a galvanometer—a well-known method. The telephone, being exceedingly sensitive and rapid, is most suitable, whilst a galvanometer would be too slow, and its use, in fact, impossible for the researches I have been making.

Numerous details have been necessarily omitted in this rough sketch of the instrument. Suffice it to say that it is perfectly adapted for the object sought, viz., the investigation and measurement of the self-induction which takes place in all wires.

By all previous methods the measurement of the resistance of a wire is taken when the current has been already some time in action, or, to use an expression of M. Gaugain, when the electricity has arrived at its "stable period." In telegraphy, electric lighting, and all applications using rapid electrical changes, another period has to be considered, viz., that during the rise and fall of the current; this he named "the variable period," and it is in this period that all the phenomena of induction take place.

To observe the *stable* period, the current is continuously passed through the bridge (and consequently through the wire under observation), and the interruptor being placed in the telephone circuit allows us to find the exact resistance of the wire, free from all induction or change in the wire itself.

To observe the *variable* period, the interruptor or rheotome (making at will from 10 to 100 contacts per second) is placed on the battery circuit, the telephone being joined as shown in the diagram.

By means of a switch or reversing key these changes are made as rapidly and often as desired.

If there were no static or self-induction, no loss of time, or change of resistance, then the result from these two periods would be equal; but this is never the case, for we find that when the resistance is balanced to a perfect zero for the stable period, loud sounds are given out in the variable period, requiring a fresh adjustment or balancing of the resistance of the wire, as well as a compensating opposing induction current from the sonometer to balance the self-induction. If we balance the resistance or the extra-currents alone there is no possible zero, but when both are

compensated we find at once a perfect zero for the resistance of the wire, and for its extra-currents. [*Professor Hughes here explained in detail the electrical communications of the experimental apparatus used by him, which was arranged for demonstration on the table before the meeting.*]

INDUCTIVE CAPACITY OF METALS.

The results of the following experiments prove that the force and duration of the extra-currents depend upon the kind of metal employed as a conductor, its molecular condition, and the form given to the conductor, independent of its resistance or the electro-motive force of the primary current. The increase of force by increased length is proportional to the length of wire less its additional resistance, but with wires of the same length increased cross section or diminished resistance does not produce a corresponding increase in the electro-motive force of the extra-currents.

The time of charge and discharge of the wire is independent of the electro-motive force of the extra-currents; for, if we compare currents of equal electro-motive force obtained from copper and iron, it will be found that the duration of these currents in wires of 1 mm. diameter will be seven times slower in iron than in copper, and a still greater difference will be found in larger wires. The longest or slowest charge and discharge take place in the purest soft iron, and have a constant ratio of increase with increased diameter of the wire; my experiments giving for wires of double the previous section, or for wires of four times less resistance, a mean increase of three times its previous duration.

The electro-motive force of the extra-current in different metals will be seen in the following table, and in order that the values obtained from the sonometer may be clearly understood I have reduced the results to comparative values.

The table of values were obtained on wires of similar length, having been repeated on a similar series of lengths ranging from 10 cm. to 5 mètres. The instrument is sufficiently sensitive for pieces only 10 cm. in length, and the results from the short lengths were as pronounced and accurate as those for greater

lengths. I may add that the instrument shows no effects or traces of static charge for the lengths mentioned.

Table I.

WIRES 1 MM. IN DIAMETER, 30 CM. IN LENGTH.

Soft Swedish iron	100	Copper...	20
Soft puddled iron	78	Brass	13
Swedish iron, not softened ...	55	Zinc*	12
Soft cast steel	41	Lead	10
Nickel*	34	German silver	7
Hardened cast steel	28	Mercury*	2
Cobalt*	24	Carbon*	1

* Being unable to procure wires of these metals, they were tested in the form of strips, and compared with similar strips of copper. Mercury was in a glass tube 2 mm. in diameter; carbon tested in the form of electric light carbon from 3 mm. to 10 mm.

The above table is only true for wires of 1 mm. diameter, as the effect depends on the size of the wire in relation to the nature of the metal. In soft Swedish iron a diminution in the electro-motive force of the extra-currents takes place with each increase in its section, and this has been partially foreseen by Maxwell,* who said: "The electro-motive force arising from the induction of the current on itself is different in different parts of the section of the wire, being in general a function of the distance from the axis of the wire as well as time."

From this I expected that the increase of electro-motive force by an increased section would not increase directly as its sectional increase; but I was not prepared to find, as my experiments prove, that after a certain maximum diameter of wire has been reached a marked decrease in electro-motive force takes place with each further sectional increase, and that this maximum is variable with each metal.

* "Electricity and Magnetism," vol. ii., p. 291.

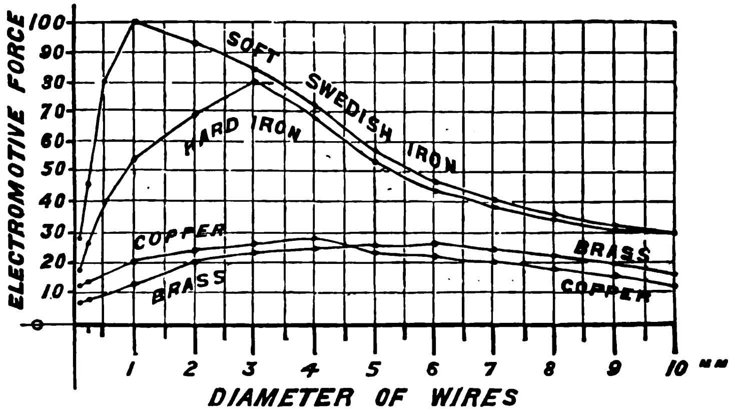


FIG. 2.

The diagram shows a rapid rise of force in soft iron from an extremely fine wire of 0·10 mm. section to a maximum at 1 mm., from which point there is a slow but continued decrease of force with each increase in the size of the wire, until at the comparatively great diameter of wire of 10 mm. the force is but a fraction more than in the extremely fine wire.

Hard Swedish iron has a less initial force in the fine wire, and does not arrive at its maximum until the wire has 3 mm. diameter, being then nearly of the same force as soft iron of the same diameter; the fall from this point is somewhat similar, but less than soft iron until at 8 and 10 mm.; soft and hard iron have absolutely the same values.

A curious change of values at different diameters will be seen in copper and brass. Copper, having nearly double the initial force in fine wires, arrives at its maximum at 4 mm.; but brass creeps slowly up, passing copper at 5 mm., arriving at its maximum at 6 mm., and finally, in the large section 10 mm., it has more force than copper, their positions being completely reversed.

I have been unable to obtain wires of different diameters of other metals; but zinc rods of 10 mm. gave a still higher rate than brass, whilst in small diameters its force was less. For non-magnetic metals it is probable that the greater the specific resistance of the metal the greater will be the diameter of the wire before the fall commences. There is no change in the relative positions of the different metals when using weak or strong

currents. The diagram shows the critical diameter of wires 30 cm. in length, but the critical diameter varies with the length, due to the increased resistance of the wires.

Carbon is remarkably free from self-induction, and although there is a rise of force in rods of 3 mm. to 10 mm., it is so small as to be hardly measurable. German silver rises with comparative rapidity, indicating that with wires of 20 mm. its force would equal that of copper. Carbon therefore seems peculiarly adapted as a resistance when used in the variable period of electric currents.

Influence of Parallel Currents.

The instrument being well adapted for showing the slightest change in the self-induction by the reaction of one portion of the current upon the other when in the same direction, as in a coil, or in the opposite direction, as in a parallel return wire, I made a series of experiments in order to observe the influence of different metallic conductors in this respect.

Two silk-covered iron and copper wires of similar diameter and length (1 mm. diam., 2 mètres in length) were each formed in a single loop of 66 cm. diameter. The extra-currents from iron were, as usual, six times stronger than those from a similar loop of copper. On closing the loop by bringing the opposite sides in close proximity and thus making a parallel return wire (the current ascending on one side and descending the other), I found that the reaction of currents in opposite direction was very different with different metals, the results depending more upon the nature of the metal than upon the proximity of the wires.

There was a reduction of the previous force of the extra-currents in iron, when forming a parallel return wire, of 15 per cent., whilst the reduction in copper was 80 per cent. Thus the currents in copper are far more influenced by an external wire than those in iron; consequently a telephone line having its return wire in close proximity should invariably be of copper, as not only is its specific inductive capacity less, but this is again

reduced by the return wire, so that its self-induction is far below that of iron.

In order to observe the influence of currents in the same direction, the same wires were formed into a close coil of twelve turns of 2 cm. diameter; and from the known effects of parallel currents in the same direction we should expect a greatly increased effect. It was so in the case of copper, but iron was far less under the influence of an external parallel current; the strength of current in iron when formed into a coil being 57 per cent. greater than that of a single wide loop, whilst in copper the increase was 404 per cent., or seven times the increase of iron; and although iron when in a single wide loop had six times the force of copper, the comparative strength was reversed when the wires were wound as a coil, the extra-currents from the copper coil then having 14 per cent. greater strength than that from iron, and this difference could be rendered more evident by employing longer wires.

Thus copper, as regards extra-currents, is far more sensitive to the influence of external currents than iron, and the true self-induction from its own current can only be obtained by a straight wire, where the return wire is at such a distance that its influence is not appreciable.

Reaction of Contiguous Portions of the same Current.

It is well known that currents in separate portions of the same wire (as in a coil) react upon each other, and I felt convinced from the preceding experiment that self-induction is entirely due to similar electro-magnetic reactions between contiguous portions of the current in its own wire. Let us assume that an electric current consists of a bundle or an almost infinite number of parallel currents, the limit being a single line of consecutive molecules; then each line of current should by its electro-magnetic action react on each of the others similarly to wires conveying separate portions of the current, and the self-induction should be at its maximum when the lines are in the closest possible proximity, as in a conductor of circular section, and far less when separated, as in one of ribbon form, where

the outlying portions are separated by a comparatively great distance: there would still remain, in the latter case, the reactions from the near portions on each other, and these should again be reduced by cutting the ribbon into a number of thin narrow strips separated, except at their junction, to a sufficient distance to prevent any marked reaction.

My experiments prove that this assumption is an experimental fact; for we can reduce the self-induction of a current upon itself to a mere fraction of its previous force by simply separating as indicated the contiguous portions of a current from each other, the results proving that a comparatively small separation, such as is obtained by employing ribbon conductors in place of a wire of the same weight, reduces the self-induction 80 per cent. in iron and 35 per cent. in copper; and if we still divide the current by cutting the ribbon into several, say 16, strips (separating the strips at least 1 cm. from each other), then the combined but separated strips show a still greater reduction, being 94 per cent. in iron and 75 per cent. in copper.

The following table shows the comparative reduction of self-induction by employing ribbons and parallel separated wires:—

Table II.

Flat Strips compared with Round Wire 30 cm. in length.	Copper.	Iron.	Parallel Wires 30 cm. in length.	Copper.	Iron.
Wire 1 mm. diameter ...	20	100	Wire 1 mm. diameter...	20	100
STRIPS.			SINGLE WIRE.		
0·25 mm. thick, 2 mm. wide	15	35	0·25 mm. diameter ...	16	48
Same, 5 mm. wide... ...	13	20	Two similar wires ...	12	30
„ 10 „ „	11	15	Four „ „ ...	9	18
„ 20 „ „	10	14	Eight „ „ ...	8	10
„ 40 „ „	9	13	Sixteen „ „ ...	7	6
Same strip rolled up in the form of wire ...	17	15	Same, 16 wires bound close together... ...	18	12

The resistance of a conductor, or even the nature of its metal, has less influence on its self-induction than the form given to that conductor, the 1 mm. wire in the above table having a less

resistance than the strip of 2 mm. wide, and a greater than any of the wider strips; but through all these variations we notice a gradual fall from the wire to the widest strip or ribbon, with a marked return to its previous force when the ribbon is rolled up in the form of a wire.

The reduction is greater in iron than copper, but its increase when rolled up is less than copper, thus agreeing with the previous observations on the difference of iron and copper to external reactions.

A still greater reduction takes place when we separate a current by using parallel wires separated 2 cm. from each other, as shown in the table. We then have a similar reduction to that produced by cutting the strips into several separate conductors; and we again remark that when the wires are brought close together (forming a stranded wire) copper rises in a far greater proportion than iron, the 16 fine iron wires twisted together as a stranded wire having 88 per cent. less induction than a solid wire of similar weight; a remarkable fact being that whilst a solid iron wire has an inductive capacity 80 per cent. greater than a solid copper wire, this is completely reversed when each metal forms a stranded wire of the same weight as the solid, for iron then has 33 per cent. less self-induction than copper. [*Lord Rayleigh, at the request of the President, advanced to the table, and after making with the Induction Bridge a few experiments with various kinds of wire, verified the results as predicted by Professor Hughes.*]

It is not necessary to use extremely fine wires when we desire to reduce the inductive capacity of iron to that of copper, for I have formed stranded wire rope of 16 strands of wire where each wire was 1 mm. in diameter, giving 75 per cent. less induction than a solid wire of the same resistance. I purchased an ordinary wire rope of 6 mm. diameter, having 6 strands of 6 wires, each 0·5 mm. diameter: this gave the best result yet obtained, for, on comparing 3 mètres of it with a similar length of solid iron wire of the same resistance, the 36-stranded wire had only 5 per cent. of the amount of induction shown by the solid wire.

Steel, in the form of ribbon or stranded wires, shows a similar effect to that of iron; and it is a remarkable fact that, whilst the

extra-currents from a steel or iron wire 4 mm. in diameter are extremely slow, and impossible to balance without reducing the time of the sonometer current (by the introduction of an iron core), the ribbon or stranded wire requires no such compensation, for its feeble extra-current is exceedingly sharp, and can be balanced to a perfect zero, being actually quicker than that of a solid wire of copper of the same resistance. This fact I regard as one of great importance for telegraph lines and lightning conductors.

A curious effect takes place if we employ mixed conductors, such as a compound wire of copper and iron. A fine coating of copper reduces the induction in a solid iron wire in a marked degree. This I found to be due to the difference of electro-motive force of the extra-currents in the two metals, for, by employing a fine copper wire parallel with an iron wire, and in contact at the ends, the extra-current was reduced 60 per cent. The copper wire, having a lower electro-motive force, probably acts as a shunt; but if the capacity of the iron has already been reduced, as in a sheet or stranded wires, then the addition of a single copper strand increases the force, as the electro-motive force of the extra-currents of copper is above that of stranded iron.

There has been for many years a discussion as to the merits of the round form as compared with the tape or ribbon form for lightning conductors. Those in favour of the former based their conclusions on experiments which gave a negative or no apparent difference between the two forms of conductors. Those in favour of ribbon conductors, as Sir W. Snow Harris, Professor Guillemin, and many others, based their opinion upon marked differences found when using high charges of static electricity. The latter supposed that there was a difference between discharges of static electricity and voltaic currents of low tension, and that the advantage recognised by almost conclusive experiments was due in a great measure to conduction by surface.

In the year 1864, Professor Guillemin and myself, as members of the Commission de Perfectionnement of the French Telegraph Administration, were charged with the mission of testing the comparative merits of the lightning protectors then used upon their lines.

Our method of experimenting consisted in joining an insulated conductor to a short fine iron wire connected directly with the earth return wire. A Leyden jar battery charged by a Rhumkorf coil was discharged through this conductor, burning or deflagrating the fine iron wire. This wire represented the telegraph instrument requiring protection, and by placing the lightning protector connected with the earth in advance of the fine iron wire we could observe the amount of protection afforded. This answered extremely well for feeble discharges, but with the full power of our battery the fine iron wire was invariably destroyed, even with the best lightning protectors which are universally used to this day. Noticing that we could not give absolute protection to the fine wire by lightning protectors, we tried the effect of joining the conductor direct to a separate earth wire in advance of the fine wire, and with powerful discharges the wire beyond the protection was invariably burnt, notwithstanding that we connected the conductor direct to earth by a copper stranded wire of 1 cm. diameter. [*These experiments were more fully described and explained by Professor Hughes by diagrams on the board.*]

Professor Guillemin continued these experiments after my departure for Russia, and he found, by employing a thin sheet of copper as a conductor to earth in place of the copper stranded wire placed in advance of the fine iron wire, that the wire could be perfectly protected. The theory of this action was not understood at the time, and the experiment has not received the attention it deserved; but the mutual reactions of contiguous currents shown in this paper explain the phenomenon in the fullest degree, for we see that a sheet or ribbon conductor has far less self-induction than a wire or rod of the same material.

I am fully convinced from the results of my experiments that an enormous retardation or resistance is evident in all conductors at the first portion of the variable period, and that this is due to self-induction, the current thus arousing an antagonist in its own path sufficiently powerful, when the primary current has a high electro-motive force, to deflagrate or separate the wire into its constituent separate molecules, as shown by Dr. Warren de la Rue.

It is also evident from my experiments—which are easily

repeated, with invariable results—that a flat conductor has far less self-induction than a solid of circular section during the variable period; and even with a constant current, as in the stable period, this form of conductor, as shown by Professor George Forbes, would, from its greater radiation, convey more current with less heating than a wire or rod of the same resistance.

Lightning conductors are intended to convey a current of high intensity during an exceedingly short time, and should therefore be designed so as to convey this current with as little opposition from self-induction as possible; consequently I regard a solid rod of iron as the worst possible form for a lightning conductor. The conductor, if of copper, should be of ribbon form, say 1 mm. by 10 cm. wide, or if of iron, of numerous stranded wires or a wide ribbon of similar conductivity to that of the copper.

Self-Induction of a Telegraph Line.

A telegraph line may be considered as a single loop: the earth taking the place of a return wire can only affect the self-induction by a diminution of its effects, as in the case of a parallel return wire.

Mr. W. H. Preece has lately read a most valuable paper on "The Relative Merits of Iron and Copper Wire for Telegraph Lines,"* in which he shows, by comparative rates of speed with the same instrument, that on a copper and an iron line of 278 miles in length (between London and Newcastle), whose resistance and static capacity were rendered equal, there was an increase of speed in the copper line of 12·9 per cent. as compared with an iron wire.

I have not been able to test the relative speeds obtainable by telegraph instruments on wires of different material. The results in every case would depend very much on the apparatus employed, but I have considered the question from a point of view independent of the instruments.

There is a remarkable difference in the resistance of a wire

* British Association, Aberdeen, September, 1885.

during the stable and the variable period, the measurements taken in the stable period giving no real or approximate idea of what its resistance really is during the rise of the current in the wire.

A curious fact in relation to telegraphy is that all measurements are made during the period of a constant flow of current, whilst all instruments—particularly those requiring rapid changes in the current—work only during the rise and fall of the current, as in the variable period. Telegraph engineers, however, have not made the mistake of assuming that there is no difference in the resistance of a wire in these two periods, as it is well known that electro-magnets and coils have a far higher resistance during the rise and fall of a current, and coils simply augment the effect of a straight wire of a given length.

The present method of testing by Wheatstone bridge has been adopted because we had no practical means of measuring the resistance in the variable period; and I do not believe that this can be accomplished except by a similar method to that which I have used, in which the resistance and self-induction are separately measured and balanced, and by the use of an exceedingly rapid and sensitive instrument of observation, as the telephone, in place of the sluggish galvanometers, no matter of what construction.

The speed of telegraph instruments is greatly influenced by the resistance of the wire. I said in 1883* that a great difference would be found in the resistance of an electrical conductor if measured during the variable instead of the stable period, and I have made numerous experiments with the view of ascertaining to what extent this difference would probably be felt on telegraph lines.

I have already mentioned that the time or the duration of the extra-currents increases rapidly with the section of the conductor; consequently comparisons can only be made between wires of similar section for speed, or wires of similar resistance for differences in their variable period.

---

* Discussion on the paper of W. H. Preece on Electrical Conductors, *Proc. Inst. Civil Engineers*, vol. lxxv., 1883.

In measuring the resistance of a wire during the two periods, I have found it best to avoid the use of resistance coils, the simplest method being to measure or balance a given length of wire in one period, and then observing how much lengthening or shortening of the wire would produce a similar zero in the second period. Suppose that we commence by balancing the resistance during the variable period, and fix the sliding communications at the point at which we have obtained a perfect zero: we can now change to the stable period by means of the commutator; and as we no longer find a zero, but extremely loud sounds, we gradually lengthen the wire under observation until we have again a perfect zero. The amount of wire added to its previous length shows the difference in resistance between a conductor in which there are rapid electrical changes and that wherein the flow of current is constant.

Amongst numerous experiments I will cite a single example. I measured or balanced the resistance of an ordinary soft iron wire, 1 mètre in length and 4 mm. diameter, during the variable period, and found that it required in the stable period exactly 2 mètres 58 cm. to balance the previous resistance. Similar tests on a sample of best charcoal iron wire, as used on our telegraph lines, gave still more remarkable results, showing 225 per cent. difference between the two periods; for 1 mètre of this wire had, during the rise and fall of the current, precisely the same resistance as 3 mètres 25 cm. in the stable period. This shows that an iron telegraph wire has with rapid currents *more than three times* the resistance during its actual work than that supposed to be its true resistance.

It was difficult on short lengths to find any change whatever in the resistance of copper or stranded iron wires in the two periods; the time of discharge being excessively rapid, I could only estimate the resistance by the electro-motive force of the extra-currents, or by forming the wires into coils (when a remarkably great difference is shown), and then estimating the proportional amount due to its own reaction; by this method I was enabled to detect 10 per cent. difference for a solid copper wire, and but 8 per cent. for the stranded rope of 36 iron wires.

The difference in time of the duration of the extra-currents between solid iron and copper and between solid iron and stranded iron is so great that we may consider a solid iron wire to belong, comparatively speaking, to the class of slow conductors, whilst copper and stranded iron would belong to the rapid.

I have shown a difference of resistance in the variable period between copper and iron of at least 200 per cent.—a difference which will be felt on instruments depending upon rapid changes, such as the telephone; and it is evident that the more rapid the contacts of a telegraph instrument the greater will be the difference between copper and iron. There is consequently a great electrical advantage in those instruments which require only a single current for each letter, as the economy of electrical impulses allows them to work at a comparatively high speed; the duration of the extra-currents would be shorter than the length of their contacts, and consequently they would perceive very little, if any, difference between the two periods, or between iron and copper. If we use three or five currents for each letter, we must necessarily send them faster or closer together; and the difficulty increases in a rapid ratio with the speed of intermittent or reversed currents, until a point is reached (as I have shown in the case of best charcoal iron) where, whilst nominally working through 500 miles, we are practically working through an equivalent resistance of at least 1,500 miles, and this without taking into account the static charge, which would, in addition, from its comparatively extreme slowness of charge and discharge, cause the apparent resistance of the wire in the variable period to be much greater than I have mentioned.

In Mr. Preece's experiments he finds a difference of speed of 12·9 per cent. between iron and copper, which is far less than the difference of resistance during the variable period which I have obtained; and this may be explained by assuming that the speed of the reversed currents which he employed was only near the border land of extra-currents. I am convinced that if Mr. Preece could have increased the speed of the instruments he would have found a far greater difference between iron and copper; and if I regard the results of a solid iron wire alone, I should consider

iron as unsuitable for telegraph instruments requiring extremely rapid currents. Copper would reign supreme if it were not for the fact, which I have discovered, that stranded iron wires have even a greater rapidity of action than copper.

Physical Changes in the Conductor.

Self-induction not only depends on the nature and form of its conductor, but also on the physical state of the metal, as already shown in the case of soft and hard iron. I felt convinced that the higher force in iron was due to its magnetic capacity, and to prove this I tried the effect of heating the wire to a bright red heat. It is well known that iron loses its magnetic properties at bright red heat, and I found that its self-induction then fell to less than that of copper. This would have been conclusive had it not been for the fact that a different result takes place when the capacity of the iron for self-induction has already been reduced, as in the case of thin flat sheets of iron: in this case there is no disappearance or further decrease of induction except that due to the extra resistance caused by the increased temperature of the strip. Now, as the strip was highly magnetic when cold, and lost this property at red heat, there should have been some change in its self-induction if this were due to the magnetic nature of the iron alone. This requires further researches before a probable explanation can be given.

Iron is peculiarly sensitive to all physical changes. Mechanical strain of all kinds hardens the wire, and its influence on its self-induction can at once be detected. An iron wire under a moderate longitudinal strain loses 40 per cent., and its capacity is then less than unstrained cast steel.

Iron well annealed has much less resistance than the same iron when hard drawn, and soft iron is generally employed for telegraph lines; but during the variable period a curious reversal takes place, as then soft iron has a higher resistance than hard iron. This apparent anomaly is easily explained if we compare the far higher self-induction of soft iron. Work is done at the expense of electrical energy, and the apparent higher resistance is due to the greater electro.magnetic action in soft iron.

An iron wire shows traces of remaining circular magnetism after the passage of a continuous current, reducing the following extra-currents 10 per cent.

Magnetising the wire, or subjecting it to mechanical vibrations, when used separately, produce no apparent change in its inductive capacity, but a remarkable change takes place if either of these is used in conjunction with a constant current. Let us pass a constant current and heat the wire to red heat, allowing it to cool with the current on; or, in place of heat, magnetise the wire; or, in place of magnetism, give the wire mechanical vibrations: the result of either of these being a strong internal circular magnetism, due, I believe, to the loosening of the magnetic molecules, allowing them to rotate with greater freedom under the influence of heat, mechanical vibrations, or magnetism. A wire thus treated has no longer its previous self-induction, which has fallen 60 per cent.; and as the circular magnetism becomes fixed when the vibrations cease, this molecular structure remains a constant as long as we employ intermittent currents in the same direction, but the structure disappears the instant a reverse current is sent; and this explains why we have more than double the amount of self-induction from reverse currents, as each reversal destroys any remaining magnetism due to the previous passage of the current.

If we compare the electro-motive force of self-induction on a given length of wire with the secondary currents generated in a second but independent circuit, we find that the self-induction is the most powerful, the secondary currents generated in a close independent copper wire being 20 per cent. less than its own wire. There is no difference between the self-induction of a current and the secondary currents; they are, as proved by Faraday, part of the same phenomenon, the self-induction being evidently due to the electro-magnetic reactions of the primary current, and as magnetism permeates space, the separation of the wires only serves to insulate the primary, but does not affect its magnetic, influence; and, as I have shown in the reactions of contiguous portions of the same current, so the magnetic reactions perpendicular to the axis of the current continue through the wire to

all surrounding wires; and if we call the currents in the independent wire secondary, they are still secondary whilst enclosed in the wire of the primary; and as the reaction will ever be the strongest in the axis of the current, so will these currents be necessarily stronger than those induced in independent wires. For this reason we should be able to obtain extra-currents of far higher electro-motive force than would be possible from a secondary wire of the same length.

It was my intention, on the reading of this paper, to demonstrate by practical experiments some remarkable properties of extra-currents of high electro-motive force; but I find that the subject and apparatus employed require a longer description than the limits of this paper allow. I must also leave aside for the present my experiments upon coils of different forms with cores of different metals. These, as well as other results obtained, indicate that there is a large field of useful research in many directions, each, however, requiring special studies according to the object we may have in view.

The record of numerous experiments, of which this paper is only an abstract, shows that the nature of the metal as well as its physical condition has an important influence upon the self-induction of an electric current, and by a study of the reactions produced by the contiguous portions of a current, and by application of the results, we may, as in the case of iron, transform an extremely slow conductor into one of the greatest rapidity; I therefore hope not only that these researches may be of interest from a scientific point of view, but that the results obtained may be of practical utility in some of the numerous applications of electricity.

Mr. C. E. SPAGNOLETTI: Gentlemen,—As Professor Perry is now present, I will take this opportunity of presenting to him the books for Dr. Oliver Lodge, and ask him to kindly convey to that gentleman the pleasant assurance that the meeting had at the proper period manifested its expression of approval of the award of the Council in regard to the presentation.

Professor PERRY: Will you allow me on my own behalf to thank you very much for having inconvenienced yourself so much

as to delay the presentation on account of my enforced absence? I have just been lecturing at the London Institution. I should certainly have regretted it very much could I not have availed myself of the very great kindness of Dr. Lodge in asking me to represent him on this occasion, for it will be remembered by the Society that I took an active part in the discussion on his paper, to some parts of which I was as antagonistic as a man who loves England is antagonistic to what he thinks are English faults. In Dr. Lodge's name I thank you for the prize which you have awarded him, and I apologise for his not coming here to receive it himself. It is very difficult to leave college duties in Liverpool during term time. I think that he may have expected me to say that his paper was not worthy of the beautiful prize which has been awarded him, but I feel that I cannot say anything of the kind, because I feel that Dr. Lodge's paper is one of the best that has ever been read before the Society.

Mr. C. E. SPAGNOLETTI: I am afraid it is too late to-night to enter on the discussion of Professor Hughes's address. The meeting has been a very full one, and it must be very gratifying to him to see so many present, and I hope we shall have on the next occasion an equally good meeting for the discussion.

Upon the motion of Mr. SPAGNOLETTI, a hearty vote of thanks was accorded to Professor Hughes for his very valuable and interesting address, which he was requested to allow to be published in the Society's Journal, together with the discussion to which it may give rise.

A ballot for new members took place, at which the following candidates were elected:—

Foreign Member:

Jacques Manne.

Associates:

Richard Aylmer.	Henry Simpson Harvey.
Gustav Binswanger.	J. M. Vernon Kent.
William Alexander Carlyle.	Sydney Morse.
Henry C. Frempt.	Walter J. Murphy.
John Dixon Gibbs.	Robert Oxlade.
Leverton Harris.	Sidney Sharp.

The meeting then adjourned until 11th February, 1886.

The One Hundred and Fifty-first Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, February 11th, 1886—Professor D. E. HUGHES, F.R.S., President, in the Chair.

The minutes of the previous Meeting were read and confirmed.

The names of new candidates for election into the Society were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Henry Crookes.	James Kenneth D. Mackenzie.
T. E. Gatehouse.	H. M. S. Matthews.
James Hookey.	Captain H. R. Sankey, R.E.

Cromwell O. Varley.

From the class of Students to that of Associates—

John P. Gorton.	William M. Meredith.

The PRESIDENT: Before the discussion upon my paper is commenced, I think it right that I should vacate the chair, which in the meantime I would ask our senior Vice-President, Sir Charles Bright, to occupy.

Sir Charles Bright took the chair.

The PRESIDENT: I should like to point out a slight omission—of a word—in my paper, which has given rise to some little misunderstanding. The table of values represented by Fig. 2 in the paper represents the results upon wires of 30 centimètres in length; and the table is perfectly true, because I have verified it fifty or a hundred times for all variations of electro-motive force. The first idea that occurs to one on seeing the table is that the result is due to one experiment only; but repeated verification with varying electro-motive forces has proved that iron always comes out the highest. The only variation that can occur would be that with a lower current the curves would fall; but they would all fall, and would retain the same relative proportions. If

wires of great length are taken, the maximum would be found at larger diameters, as the increased resistance interferes with the result on the smaller wires; but the curves are true, as regards electro-motive force, for any length.

Sir CHARLES BRIGHT: The question we have before us is one of very great interest and importance. I do not know, among our members or friends who are here present, that anyone has paid more attention to the delicate effects of induction than Lord Rayleigh, and I shall be extremely pleased if he will favour us with his views upon the subject.

Lord RAYLEIGH: It is quite true, Sir, that I have given attention to some of the points touched upon by Professor Hughes in his very interesting paper; but that paper contains a good many other points which are quite new to me, as also, I suspect, to most others.

I observe that on the first page of the paper Professor Hughes does not employ the term "self-induction" in quite the same sense—or, at least, with quite the same definiteness—as it has been used by mathematicians, especially by Professor Clerk-Maxwell, who used the term to express an absolutely definite quantity, dependent almost entirely upon the exact form of the electric circuit, and, with one exception, independent of the material of which the circuit is composed. The exception would, of course, relate to the use of the magnetic metals—iron principally—and also nickel and cobalt. If we exclude those metals, and if we ignore (which, I think, for such a purpose as this we might certainly do) the very feeble magnetism and diamagnetism of other metals, then we may say that the self-induction is independent altogether of the material forming the conductor. There is, of course, another element entering into the matter, and that is the resistance of the circuit; that, again, is a perfectly distinct quantity. If we take the ratio of those two quantities, the coefficient of self-induction being on the electro-magnetic system of measurements a linear quantity, and the resistance being a quantity of the nature of velocity;—if we divide the self-induction by the resistance, we get a quantity of the nature of time. [*Explained on the board.*]

This time constant of a circuit (I believe I was the first to use the term in a paper some twenty years old,* "On an Electromagnetic Experiment") may be arrived at by a Wheatstone bridge arrangement somewhat similar to that which Professor Hughes describes, in which we have, say, one only of the sides of the quadrilateral possessing in an inappreciable degree this quality of self-induction, the other sides of the quadrilateral being made up of what we may call "self-induction-less resistances;" although Professor Hughes will tell us that such a thing cannot exist, because whenever we make a connection between one point and another there will certainly be some self-induction, sensible at any rate in iron and in steel, though usually negligible compared with the self-induction of a coil of many turns. A galvanometer is in circuit, and the arrangement is the ordinary one for testing resistances by Wheatstone bridge. If we observe the indication on the galvanometer in what Professor Hughes calls the "stable condition" of the current—*i.e.*, first make the battery contact, and afterwards make the galvanometer contact—then, as we all know, we shall obtain a balance at the galvanometer only when the four resistances are in proportion, and the conclusion is entirely independent of the self-induction that may be possessed by one or any of the sides of the quadrilateral. I never quite know what is the recognised word in describing this arrangement. If one talks of the "bridge," one is in great danger of slipping into speaking of the four arms of a bridge, or something of that kind; when one calls it a "quadrilateral," I suppose there is less danger of confused metaphors. But now, instead of making first the battery contact, and afterwards the galvanometer contact, we, having already adjusted so as to get a perfect resistance balance, first close the galvanometer contact, and afterwards make the battery contact; then we know that there will be a galvanometer indication at the first moment of closing, and the throw of the galvanometer will afterwards subside, and ultimately come to rest at zero, as though the connections had been made in the reverse order. But from the amount of the throw so

* *Phil. Mag.*, June, 1870.

observed we may get information of the amount of self-induction in one branch, supposing there to be no appreciable amount of self-induction in the other branches; or, if there be some appreciable self-induction in the other branches, it gives us the relation among them. That is the method which Clerk-Maxwell proposed for determining the self-induction, and I am well acquainted with it, for I have used it myself for elaborate measurements of the self-induction of a coil of a great number of turns in connection with my determination of the absolute unit of resistance. The galvanometer needle shows a throw caused by the self-induction of the circuit, and in order to interpret that indication—in order to eliminate the sensibility of the galvanometer and the other constants of the arrangement—the resistance balance is next upset in a known manner by adding or subtracting a small resistance. In that case a steady deflection of the galvanometer is obtained, by the observation of which, in conjunction with the observed value of the throw of the galvanometer due to self-induction only, when there is a perfect resistance balance, we may obtain that quantity which is the ratio of the self-induction to the resistance; it is a quantity of the nature of time, and in this method of measurement comes into comparison with the time of the swing of the galvanometer needle. In that way we can observe the time constant of the circuit formed by the coil, which gives us the ratio of the coefficient of self-induction to the resistance; and if we know the resistance (I do not say in the terms of arbitrary units, but in the terms of true ohms), then from that information, and with the knowledge of the time constant, we can infer the value of the coefficient of self-induction. For many purposes that step is not required, and only the time constant comes into question. Whenever we have to do with rapidly varying currents the self-induction, or mutual induction, becomes of great importance, and very often the question of resistance falls comparatively into the background. It is easy to put cases in which the resistance, in practice, is almost a matter of no concern, and everything depends upon the coefficient of self-induction. The magnitude of the effect observed in the above arrangement on the galvanometer, when contact is first made at the galvanometer, and afterwards at

the battery, depends upon two things: it depends upon the coefficient of the self-induction of the coil, and also upon the current flowing through it. We may imagine that at the first moment of contact there is no current flowing through the coil; at the end of a small interval there is a certain steady current flowing through it, the amount being determined by the resistance and the electro-motive force brought into operation; but the electro-motive impulse which acts on the branch producing the throw of the galvanometer needle is made up of the two factors—of the coefficient of self-induction and the current. [*Diagram and formula shown on board to illustrate this.*] Now one question arises—whether in the precise arrangement which Professor Hughes employs (and which all of us admire for its ingenuity and convenience) these two quantities are sufficiently separated, because it seems to me that this is rather a difficult problem. You may remember that Professor Hughes takes his observations (not upon a galvanometer, but upon a telephone) by balancing the self-induction of the one side of the quadrilateral by an induced electro-motive force obtained by the mutual reaction of a coil in the battery branch with another coil in the telephone branch, one being adjustable in relation to the other, so that the mutual effect could be varied. That arrangement would work without the slightest ambiguity if the question were to compare the self-induction of two similar coils or two separate pieces of wire, provided the only difference between them was the difference of self-induction; but, unfortunately, in most cases, if we take two wires, or two coils—of the same length and of the same diameter—of wire, there will be another difference between them besides the difference of self-induction, and perhaps a much greater difference, namely, that of resistance. For instance, take the extreme case of a straight iron wire in the one case, and a straight copper wire in the other, of the same length and the same diameter: of course the resistance of the iron wire would be much greater—some dozen times greater—than the resistance of the copper, and on account of that altered resistance there will be a difference in the value of the current (which I call x) which will ultimately establish itself in *that* branch, and consequently,

even if the self-induction were unaltered, there would still be a change of the electro-motive impulse due to the change of the magnitude of the current; and the question is how far the one thing can be perfectly separated from the other in the form of apparatus that Professor Hughes has employed. The experimental question is not a very easy one to solve. Clerk-Maxwell gives two arrangements for the determination of the coefficient of self-induction. I do not know that either of them would be very convenient for this special purpose of comparing moderate lengths only of wire under such conditions as Professor Hughes has tried them, and certainly nothing could exceed the convenience and facility of adjustment of Professor Hughes's arrangement.

Now as to the results. Since the paper was read a fortnight ago I have been refreshing my memory and looking up some parts of Clerk-Maxwell's great book, and I find there some results which are to a very great extent similar to the conclusions arrived at by Professor Hughes experimentally, particularly as to the effect of the magnetic quality of iron in the conductor. I may say that I have come across one or two mistakes in Clerk-Maxwell's exposition: one of them is probably of the nature of a slip of the pen or a misprint; the other is perhaps more serious as a matter of principle, but not of much importance practically. Maxwell takes the case of two very long parallel conductors in the form of cylinders, their internal and external radii being both specified. In that way he obtains the value of the coefficient of self-induction per unit of length, in terms of the four radii of the cylinders that have to be considered—the inner and outer radius of the one cylinder which conveys the current, and the two corresponding radii of the cylinder by which the current comes back. [*Sections of cylindrical conductors described on the board.*] Of course with these four quantities the result is pretty complicated, and I do not think it necessary for me to deal with that. I will only take the case which Maxwell falls back upon in which the hollow parts in the two cylinders are suppressed so that they become solid wires.

$$\frac{L}{l} = 2\,\mu_o \log.\,\frac{b^2}{a_1\,a_1'} + \tfrac{1}{2}\,(\mu + \mu')$$

In this formula L is the self-induction corresponding to length (l) of the cylinders; a_1, a'_1, are the radii; b the distance between the centres; μ_o the magnetic permeability of the intervening medium; μ, μ', of the material of the cylinders. In all ordinary cases $\mu_o = 1$.

Maxwell says that except in the case of iron we may suppose all the quantities μ in this formula to be unity, in which case we obtain a simpler result. Now in the case which Clerk-Maxwell there excludes, but which is the one that Professor Hughes has dealt with perhaps more fully than any other, in which the material of the wire is iron, that is as far as possible from being the case, the difference in the values being some 300 or 400 times in the case of the wires being of iron as against the value if they were of copper or of some non-magnetic metal. One slight correction of which I spoke—and perhaps I ought to mention it because I am quoting the formula, although I believe it is of no importance—is that as depending upon the distance of the two wires the formula is not perfectly correct except in the case where the magnetic permeability can be neglected; where the μ's are all alike the formula is perfectly correct, but if they are not absolutely the same then a slight alteration will be required. I think it is a slight oversight in Clerk-Maxwell's work, but it is of no importance at all for our present purpose. Well, now, if we deal with the case of copper, or a non-magnetic material, then the first part of the expression is quite as important as the second, and the coefficient of self-induction increases as we separate the two wires—*i.e.*, increase the value of b, the distance between the centres—and the increase is absolutely and completely given by this formula.

One of the points which Professor Hughes brings out so ably is this—that when the wires are composed of iron it does not make much difference whether or not the circuit be open—whether the wires be almost in contact or at a considerable distance apart—whereas with copper and other metals it does make a great difference. That is exactly what this formula tells us, because in the case of iron the second part gives us the most self-induction, and corresponds to the magnetic condition within the iron conductor; it is least in the case of copper. In the

latter case, the second part, though not to be neglected, is comparatively of no great importance—not so important as the first part, which depends upon the distance of the conductors—the extent to which the circuit is open.

In consequence, Clerk-Maxwell states—what is evident when one has once clearly got the idea into one's head—that by sufficiently opening out, by sufficiently separating each conductor—*i.e.*, flattening out each wire into a strip, and by bringing the strips so flattened out into intimate contact with each other, thus bringing the out current and the return current into sufficient proximity with each other at every point—the effects of self-induction may be diminished without a theoretical limit; but Maxwell gives no results of calculation. The matter appeared to me to be of some interest (and I should say that the whole of what I have said about it is entirely the consequence of Professor Hughes's paper, for I had never thought of it before), and I took a case for calculation somewhat simpler (although less practical) than the one taken by Maxwell, which is a most difficult one, because the system of magnetic forces due to the current in the iron conductor is modified by the mere fact of the presence of a mass of iron close to it, independently of any current in the mass of iron—the point overlooked by Maxwell. To take the case from a simpler point of view, and which gives us, I think, some information in connection with this apparatus, let us take that of one conductor entirely enclosed within another [*drawing on the board*]—say one tubular or cylindrical conductor, with an internal one—through which a current passes, separated by an insulator at a convenient space. Such an arrangement is much simpler to calculate than the system adopted by Maxwell, and can without difficulty be worked out. Consider the value of the coefficient of self-induction per unit length; and then, whether the material be iron, or whatever it may be, providing we know its μ or coefficient of permeability, and whatever may be the four different radii, the result is a mere matter of calculation, which I need not trouble you with, but which I may take some other opportunity of publishing. The case to which I should like to draw your attention—an extreme

case—is obtained by introducing some simplifications. The first is, that the intervening space is reduced without limit. This cannot be done in practice, because room must exist for insulation, but that is a thing which can be easily understood. Imagine then that this intervening space is reduced so that the outer surface of the inner cylinder comes to coincide with the inner side of the outer cylinder: that will give us now only three radii. Then I suppose both cylinders are formed of the same material, so as to have the same permeability; that is the second simplification. The third simplification I take is to suppose that the cylinders are exceedingly thin in comparison with their radii. So that the system becomes two thin cylinders in intimate contact with one another, one conveying the outgoing current, the other the return current. You will see that my aim is to get a circuit in which the self-induction shall be very small, by bringing the outgoing current and the return current into close proximity—closer proximity than is possible in the case of solid conductors. To carry that out I call the common radius r; to define the other radii I will suppose that the sectional areas of the two cylinders are the same, and equal to πc^2, so that c is the radius of the circle of equal area. For this system the result is

$$\frac{L}{l} = \frac{2}{3}\frac{\mu c^2}{r^2}\left\{1 + \frac{1}{10}\frac{c^4}{r^4} + \;\; . \; . \right\}.$$

I have given two terms, but in what I am about to say will confine myself to the first. We see that, as might have been expected, the quantity $\frac{L}{l}$ (which can only be numerical, as the ratio of two quantities both of which are linear) depends upon the ratio of the thickness to the radius, and upon the inductive permeability (μ) multiplied by the numerical factor $\frac{2}{3}$. Thus we see that the special point is that, keeping c constant—*i.e.*, keeping the aggregate area of the two conductors constant—and increasing the radius, we may reduce the coefficient of self-induction to any extent we please. This formula brings out in an exact manner that which Maxwell states without making any express calculation. This theory that I am endeavouring to explain recognises two qualities in the material—the quantity μ, upon

which and the form the coefficient of self-induction alone depends, and the resistance, which may be taken to be either the actual resistance of the conductor, whatever its shape, or, if we like, as the specific resistance of the material of which it is made. Now one question raised by Professor Hughes's experiments is this, Is that really in conformity with experiment or not? I am not quite sure what Professor Hughes's answer will be—whether he thinks that, excluding the difference between one material and another as regards the magnetic quality (which practically, I imagine, only excludes iron, nickel, and cobalt), there is any other difference in the material which is not accounted for by their resistance. I understand Professor Hughes to speak of carbon as specially favourable; but that seems hardly to agree with this, because between carbon and copper, or carbon and German silver, I imagine there can be no difference worth considering in the value of the magnetic constant of permeability. If that is correct, any differences between the carbon and copper or German silver would be a question of resistance only, and of a kind which therefore is thoroughly familiar to all of us. I confess that doubt existed in my mind whether some of the results which Professor Hughes has brought forward, and which do appear to indicate such a difference, do not depend rather upon the peculiar character of his instrument, in which there is not a complete separation between the effects of induction and the effects of resistance.

One point struck me as of very great interest, and which no doubt all present appreciate fully from its practical bearing—that is, the difference between a stranded iron conductor and a solid iron conductor. I do think that difference important and striking, as it has, so far as I know, not been hitherto remarked upon; but it is not difficult of explanation, because if the conductor is stranded it is evident that the magnetic cycle is more interrupted. In solid iron wires the magnetic induction follows a continuous path in iron; in the stranded wire there are interruptions whose effect is relatively very considerable, just as in dynamos the magnetism is greatly obstructed by the relatively small air space between the armature and the pole pieces of the field magnet.

Therefore practically it comes to this—that the value of μ for the stranded conductor is probably a great many times lower than it would be for a solid conductor; and the point strikes me as one of very great interest. I think Professor Hughes even goes the length of saying (and this bears upon what I was speaking of just now) that with a stranded iron conductor the self-induction is less than in a copper conductor.

Professor HUGHES: Yes.

Lord RAYLEIGH: I cannot understand how it can possibly happen.

Professor HUGHES: If compared with a solid pure copper wire, and the iron very much divided and of very fine wire——

Lord RAYLEIGH: Stranded?

Professor HUGHES: Yes; particularly when the copper wire is compared with a thin iron sheet of the same resistance.

Lord RAYLEIGH: If it is true in the sense in which Maxwell uses the term, it gives something essentially new.

Professor HUGHES: Well, that is what it does.

Lord RAYLEIGH: And that is the point which I hope will be fully elaborated, and not be allowed to drop.

Professor HUGHES: I should like to prove it to you this evening.

Lord RAYLEIGH: My doubt is whether in the experiments in which the self-induction of the iron appears to be less than the self-induction of copper the result may not be due to some other circumstance, such as the section being different. What is the form of the copper?

Professor HUGHES: Wire or flat, provided each strip has the same resistance and same thickness.

Lord RAYLEIGH: I have no doubt the difference is thoroughly capable of explanation, and will not remain long at issue; but I should rather expect to find that it depends upon some misunderstanding, or different use of terms, than upon some new quality different either from the specific resistance or from magnetic permeability.

Professor HUGHES: Allow me to say that it is not only resistance; because if you take a narrow thin strip of the material, which has high resistance, you have more induction than if you

take a wider piece. You can diminish the resistance of a strip by using a wider strip of the same thickness: the wider the strip the less the induction.

Lord RAYLEIGH: I have no objection to Professor Hughes proving that a new quality does come into the question; it will be interesting if it does. I thought that the effects of stranded wires and the remarks upon lightning conductors were some of the most interesting points that were touched upon in his paper. It certainly never occurred to me that the self-induction of a lightning conductor would be important enough to come into the practical question, but after Professor Hughes's description, and what he has pointed out, it seems by no means unlikely. I do not know whether all are agreed as to what exactly is to be expected of a lightning conductor—whether we should consider that its function is to be able to carry off a very strong but short-lived current safely away. I suppose that is one use of it; but Maxwell, and, I think, some other authorities, rather leaned to the belief that the function of a conductor was rather to prevent the electricity ever accumulating up to the striking point, by establishing a good communication between the earth and a point elevated at the top of the building, or wherever it may be, and so to cause such a gradual leakage away of the accumulated electricity as to prevent anything like a powerful disruptive discharge occurring. We should be glad to hear Professor Hughes's views upon these points.

Professor HUGHES: It should fulfil both conditions.

Lord RAYLEIGH: Professor Hughes held out a sort of invitation at the end of his paper for others to contribute anything that might be in their possession which might bear upon this subject. In response, I may perhaps be allowed to mention (without detaining you long) some experiments that I have been making lately, and which were directed to test a point which seems to me of considerable importance, but which as yet, I believe, has not been examined experimentally—that is, as to the behaviour of iron and steel (I think they are alike in this respect) under excessively small magnetic forces. Some members are more concerned with what iron will do under the influence of very

great forces; but the behaviour of iron and steel under very small magnetic forces is nevertheless a point of considerable practical importance, as you will see if you think of what happens in a telephone. In fact, the theory of the telephone, as ordinarily presented, distinctly assumes that under the exceedingly small magnetic force every part of the iron does respond and take up a magnetism of sensible magnitude; and yet, in face of the successful operation of the telephone—perhaps I ought not to say so; I think the telephone might be explained in any case—at any rate, in face of the usually received explanation of the telephone, some first-class authorities on the subject, such as Professor Ewing, hold, or incline to the view, that if the magnetic forces were sufficiently reduced, the magnetic response—the magnetisation of the iron in response to that force—would tend to become not only absolutely, but relatively, smaller and smaller; and Professor Ewing evidently inclines to the view that a finite amount of magnetic force is necessary in order to produce *any* change in the magnetic condition of the iron. Well, if that were so, it seems to me that either the telephone would not act, or, at any rate, that we should have to explain it differently from what is usual; and I accordingly instituted some experiments in order to test that point, and the conclusion that I have come to is pretty definite. It is, that the response of the iron to the magnetic force is perfectly uniform and perfectly proportional to the force. My means of measurement enable me to say this, within 10 per cent. throughout; and the lowest limit that I was able to conveniently work to was about 1-1000th of the horizontal magnetic force of the earth. Between that very small magnetic force and a force—varying to some extent according to the nature of the material, whether it was iron, soft or hard, or steel—of about one-fifth of the earth's force, the effect seemed to be in proportion; so that this quantity μ is a definite constant extending to magnetic forces of that amount, although we know that when we much exceed this magnetic force the behaviour of iron is much more complicated. Ewing and others have shown that when in the case of very soft thoroughly annealed iron the magnetic force reaches, I think, about twice or thrice the earth's horizontal

force, the iron magnetises suddenly, and almost instantaneously runs up with immense rapidity to the neighbourhood of the point of saturation, after that, of course, not increasing much more. But if we keep quite clear of the point at which that effect begins—and I think we do so by keeping the force below about one-fifth of the earth's horizontal force—then the effect seems to be perfectly simple, and the magnetisation of the iron will be in very close proportion indeed to the force which calls it out. I do not quite know whether the amount of magnetic force in Professor Hughes's experiments can be estimated. Of course it is only the iron near the circumference of his wires that would be magnetised; the iron in the centre is not subject to the magnetic force, and plays no special part. It is the iron in the outer parts of the conductor which are exposed to the magnetic force in virtue of the current flowing in the inner parts; but whether that magnetisation approaches saturation, or, if not approaching saturation, approaches the point at which the magnetism increases much faster than the magnetic force, I do not know. If it does, the μ is an uncertain quantity; although mathematicians may call it a constant, it has hardly any claim to the name. But if the currents are small enough, then, I think, μ would take the character of a constant, and most of the ordinary calculations which mathematicians make would be practically justified. I must thank you for the attention you have given me.

Sir Charles Bright: We have present to-night one of our members and friends from the other side of the Atlantic—Mr. Frank L. Pope, the well-known electrician, of New York, whom I had the pleasure of seeing there; and I would ask whether he has anything to say upon the subject of the paper under discussion.

Mr. Frank L. Pope: My time has been so much occupied since the last meeting of the Society that I have had little opportunity to study Professor Hughes's paper, or, in fact, to read it carefully, although it is one of the most interesting papers that has ever come under my notice. I therefore can only speak briefly on two or three things that suggested them-

selves to me on casually reading the paper during the little time I have had to devote to it. It is now nearly thirty years since I, as a boy, entered the telegraph service of the United States. I was employed for many years as a practical operator and sort of electrician. That was back in the dark ages of telegraphic science, as we all know, and of course we met with a great many phenomena that we were not able to explain at that time, and many others which we explained wrongly. A considerable portion of those effects have been sufficiently well explained since that time; but there have been two or three that I must confess I never saw the reason of until I heard Professor Hughes's paper the other evening. The first one that I noticed was a matter that I think everyone in the telegraphic service has often observed—that is, the destruction of an instrument, the burning of the electro-magnet, by atmospheric electricity passing beyond a ground wire attached to the line of very low resistance, almost infinitely small compared with that of the instrument, and much smaller than that of the same length of the line wire by which the atmospheric current came to the instrument. That is something that has always been a mystery to me; but I think it is well accounted for by the experiments of Professor Hughes. At the time I speak of, when I entered the American telegraphic service, type printing instruments were quite extensively used on the lines. We had the beautiful make-and-break apparatus of Professor House, which, I think, some attempt was made to introduce into this country. I think our Chairman of this evening was connected with the enterprise in some way. We had quite a large number of these in operation, and we also had the then recently invented apparatus of Professor Hughes. Both kinds were in use—the "House" to quite a large extent, and the "Hughes" to a limited but increasing extent—at the time of my becoming connected with the service, so that I became quite an expert operator on both of these instruments. We noticed in connection with the "House" instrument—which I say was a make-and-break instrument, working at the rather extraordinary rapidity of some 35 and 60 interruptions per second, over lines 100 to 150 miles in length — we noticed, or we thought we

noticed, that that instrument worked very much better with a stranded wire than on a solid wire. We had some stranded lines at that time as well as solid ones. We knew nothing about the specific resistance of a line at that time, having no means of measuring it; but we could tell, by putting the same battery on, that if we got the same current the lines were about equal; and there was a great difference in working: the rapidity was greater with a stranded than with a solid conductor.

Professor FORBES: Iron wire?

Mr. F. L. POPE: Yes; iron wire which had been passed through boiled oil. We found that effect very difficult to account for, and the only explanation attempted at that time was that it was a circumstance which went to show that the current was conducted on the surface of the metal instead of through the body of it; and we never had any better explanation of it that I know of until Professor Hughes explained it. One other matter in connection with the paper occurred to me. It was pointed out, I believe, by Mr. Preece some time since that a considerably increased speed was obtained with an automatic receiving instrument, by connecting the coils of the magnet in parallel arc instead of in series in the usual way; *i.e.*, that with two magnets, of coils of the same resistance, one having large coils connected in series, and the other having smaller coils connected in multiple arc, the latter would respond more rapidly to the signals than the former. I do not know of my own knowledge to what extent this is true; but I suppose, as it has been referred to by Mr. Preece and others, that it must be some difference, if not a considerable difference, and I think it is capable of explanation on the same theory. One thing more. We have attempted a good deal in the United States, without any very great commercial success, to work what is known as the "Bain Automatic" system of telegraphy. A punched strip is used for the transmission, and the currents are received upon an electro-chemical instrument. We were able as long ago as 1870 to get a speed of a thousand words a minute between New York and Philadelphia—a distance of 100 miles—in the ordinary double line of characters; but it was only possible to do that on a particular kind of line wire that was used considerably in the United States at one time, and

some of which is used even yet—a compound wire with steel core and a copper sheathing. We have never been able to get such a speed with any other kind of conductor. I do not say it could not be obtained with copper wire, because I do not know that it has been tried, but nothing like it could be got with an iron wire of the same resistance. This point is referred to in the paper. It is said that the copper probably acts as a shunt; but it is a very interesting circumstance, and I mention it as confirming the experiments of Professor Hughes.

Sir C. BRIGHT: I know that Professor Forbes has given a great deal of attention to this subject, from some communications I have seen of his, and I should be glad to hear his remarks upon the paper from the abstract science point of view. Mr. Pope has favoured us with some observations on the practical side.

Professor G. FORBES: I am very pleased, Sir, that I have been called upon to speak this evening, because I can easily foresee that this discussion is going to last for several evenings, and I am particularly anxious to make a few remarks in the presence of Lord Rayleigh, because I want to discuss the views I have formed, afterwards, with him. First, however, there are certain practical points in Professor Hughes's paper which must strike all concerned; that referring to stranded wire for telegraph service seems to be a very important one, and will have to be fully discussed. Another point, which Lord Rayleigh drew attention to, is that very remarkable amount of self-induction in a thick copper wire which, with a lightning discharge, actually allows the thin iron wire to fuse preferably to sending the current down the thick copper wire. That fact has a beautiful analogy in mechanics, where the bursting of a gun is caused by putting a soft plug of earth or snow in the muzzle. The resistance offered by the plug to being pushed out is very much less than the resistance of the barrel of the gun, but the air is pushed out by the gas formed by the gunpowder more rapidly than the pressure can be communicated through the air to the obstruction, and the question arises, What force is required to push out that snow suddenly with the velocity with which the air is travelling? The pressure comes out, on calculations I made, at something like

seven tons to the square inch, which of course bursts the barrel. This effect of mechanical inertia is quite a parallel with Professor Hughes's lightning discharge, which is a case of what Maxwell speaks of as the electro-kinetic momentum in the electrical arrangement. There is a third practical point which is not so much illustrated in the experiments described in Professor Hughes's paper as with some further experiments which he was kind enough to undertake in connection with some theoretical notions that I ventured to throw out with regard to the influence of an iron sheath round a conductor. In such a case the self-induction becomes enormously increased, as we could easily see from theoretical grounds, and I trust that this investigation may lead to some practical modification of the construction of submarine telegraph cables. For many years I have tried to impress upon those who have had a great deal to do with the construction of telegraph cables in the past what an important point this seemed to me; but the importance of it is proved more evidently by the experiments of Professor Hughes: that is to say, that by surrounding the cable with a sheath of iron instead of surrounding it with a sheath of gun metal, or some other non-oxidisable and non-magnetic material which is sufficiently strong, we are introducing an enormous amount of self-induction. I may remind you that Van Rysselberghe, in Brussels, has toned down the sharp signals of the Morse code so as not to interfere with the telephone by means of passing the current through an electro-magnet first; and I believe that I am not wrong in saying that the self-induction produced by one of our Atlantic cables is probably greater than the self-induction which could be produced by any of the most powerful magnets which have ever been constructed.

I wish now to say a few words about the theory of the phenomena which have been brought forward by Professor Hughes; and I speak on the subject with some little knowledge of his method. I have been fortunate enough to have been in correspondence with him for a considerable time back while he has been carrying on these experiments, and he was good enough one or two months ago to introduce to me his own apparatus

which he has used in them. That apparatus is of a very different kind in appearance to the beautiful set which is before us, but it is a piece of apparatus in which every part has been made by his own hands, with a perfect knowledge of exactly the requirements of each bit. I may say here that as soon as I had tried some experiments with him in his own room, nothing would satisfy me but that I must set up an induction bridge of my own, and I naturally proceeded to do so. But let me warn anybody that thinks of doing the same, being bitten with the interesting character of the instrument as I have been, that they will have to use care. They will find out that it is not such a very easy thing to make that very simple induction apparatus that Professor Hughes has shown us; the amount of care and thought that has to be exercised in the construction of it is something very great indeed. At first it looked a very easy thing, but I had to throw away the first three or four bridges before I got one that satisfied me.

In thinking of the theory of this effect I have been impressed with the feeling that I should have to do that which is a very unpleasant thing. I know it is a very unpleasant thing, when anybody brings some new experimental facts before us, to raise the remark that it is all foreshadowed in "Maxwell;" it is such a very common thing to happen, and it is almost invariably the case. I confess that when Professor Hughes first told me of the result which he was arriving at, my first impression was, "It is all in 'Maxwell;'" but the more I got to investigate the meaning of his results, and the more I worked at it myself, the more I saw how little I had understood the work of Professor Hughes, and what very novel results he did seem to bring before us.

In the same way as Lord Rayleigh, I had great difficulty in understanding the exact meaning that could be attached to Professor Hughes's measurements. Naturally, one's first attempt was to get at the coefficient of self-induction. My notion at that time was that if we have a coefficient of self-induction we have everything, and I naturally tried to get out of these experimental data the means of determining the coefficient of self-induction. That is, I am afraid, almost impossible to get at;

but I think we shall find, in looking to the thing closer, that the coefficient of self-induction is not the only thing in the phenomena, but that Professor Hughes has actually brought before us a point which has not been touched upon before by any investigator. Professor Hughes employs three terms: he uses the term "induction" and the term "electro-motive force" in a peculiar sense, and he uses the term "resistance;" and I think that most of us who have tried to get at the bottom of these experiments have been a little puzzled by the meanings of these three terms. The term he uses as electro-motive force, however, means generally the electro-motive force generated by self-induction, and measured by the double-coil arrangement which he calls a "sonometer." The resistance term is a different thing—it is the resistance measured by Wheatstone bridge; and that there should be any difference, as in the table, is a remarkable thing.

Professor Hughes not only makes his contact, but also breaks it. In the one case the self-induction of the apparatus will increase the resistance when contact is made, but when the contact is broken it will diminish it; and therefore, if you are making and breaking the contact, you cannot, according to what I believe is really the ordinary theory—and the only theory known hitherto—get any approach to an adjustment by moving the bridge. Thus it would appear that what Professor Hughes has measured as the resistance is something different, and yet it is not a thing which changes sign with the increase or decrease of the current as the electro-motive force of induction would. When you are increasing the current you are producing a counter electro-motive force, which is the self-induction; when you are diminishing it you are producing an electro-motive force in the same direction. Now Professor Hughes's sonometer arrangement is arranged so as to bring a counterbalance upon that part of the effect which changes sign with an increase and decrease respectively of the current; because, when the current is increasing, the induction in the sonometer is in the one direction; when the current is diminishing, it is in the opposite direction in the sonometer.

Now Lord Rayleigh has touched very fully upon all those points in which Professor Hughes's results were anticipated by

known formulæ in Maxwell's work; but they do not go so far as several of Professor Hughes's results: they do not explain why, when the size of the wire is increased, the reading on the sonometer gradually diminishes after a time, and why there is a maximum thickness of the wire which gives a maximum reading on the sonometer. I think, however, that we can not only say why there is a diameter which gives a maximum reading on the sonometer, but we can also at the same time see what Professor Hughes means by the altered resistance in the variable period. If we have a single wire whose coefficient of self-induction is L, we have been in the habit of saying that if there is a current started in one direction (c), then there is a counter electro-motive force equal to L $\frac{d\,c}{d\,t}$, or L times the rate of variation of current. If we have a number of wires parallel, so as to form a strip, what will then happen? Each of these is influenced by the induction of its neighbour, and the central part is most influenced, as will be evident to you when you notice that the average distance of the others from a central wire is one quarter the breadth of the strip; but the average distance of the wires from one of the outside ones is half the breadth, and therefore in a strip of wires the inside parts have the most induction in them, and the counter electro-motive force on making contact is greatest there. With a large cylindrical wire the difference is still greater. Maxwell treats the problem in a way which one would have thought would have led to a complete solution of it. In one problem he considers the whole current which is flowing through the conductor and calls it C, and he determines what electro-motive force is required to send a current (C) through it when C is varying, and he got out the formula, which I may put in this way—

$$\text{Electro-motive force} = \mathrm{R\,C} + \mathrm{A}\frac{d\,\mathrm{C}}{d\,t} + \mathrm{B}\frac{d^2\,\mathrm{C}}{d\,t^2} + \&c.$$

The terms after the first depend on the variation of C, and can only be indicated on Professor Hughes's apparatus by the sonometer, except in the case of a harmonic variation. The first term is the pure resistance, measured in the stable period, multiplied

by the current. Thus, in this case, where we should have expected Maxwell to have arrived at a solution showing the difference in resistance which Professor Hughes is obliged to make in order to get silence, we do not find that change of resistance in Maxwell's formula. The reason I apprehend to be this—that in Maxwell's problem he has assumed the partial currents all to be in the same direction as the total current. Now I have shown that in a strip the counter electro-motive force on making the contact is greater at the centre than it is at the sides; still more so is it, as is well known, in the case of a circular conductor—a wire: it is then far greater at the centre than it is at the sides. Thus we may consider the whole circuit to be like a battery going to a divided wire, each part of which has a battery acting in the opposite direction to the main one. These two batteries represent the E.M.F. of induction in the central and outside parts respectively; and we all know what happens in that case. The currents are divided between the different circuits in a proportion which depends upon the different electro-motive forces, and on the resistances; and if the resistance of the outside of the wire is small, and the E.M.F. of induction less than at the centre of the wire, then the electro-motive force of induction at the centre actually causes a current to circulate round, going from the centre longitudinally, and back by the outside. You will notice that I have spoken at the present time of the energy which is being consumed in the solid body of the wire at the moment of *making* the contact. Now at the time of *breaking* the contact the effects are reversed, but are exactly similar in character, and exactly the same current will be found to be circulating around, though in the opposite direction. Thus the same energy is used in making the contact as in breaking the contact, and in neither case does it depend upon whether we are increasing or decreasing the current. Thus the energy which is being thus consumed produces a resistance to the current, but not a resistance in the nature of an electro-motive force, which may be with or against the current, but of the same nature as the resistance which the wire itself contains—a resistance which could not be balanced by the sonometer, which does not vary its sign with the increase or decrease of the current, but

which only could be balanced by a change in the position of the attachments on the bridge, indicating a totally different resistance in the variable period to what it is in the stable period. I believe I am right in the supposition. I was particularly anxious that I should speak in the presence of Lord Rayleigh, because I am sure that he will correct me immediately if I am wrong. But I could occupy a great part of your time by going into a large number of these experiments which are completely explained by assuming this explanation to be true, and which are not explicable on the old theory. I will only just briefly refer to that most remarkable set of curves which Professor Hughes has given us, and which he drew a short time ago on the blackboard. If we measure the effects upon a fine wire, then the resistance of the outside parts is comparatively great, and the sonometer effect is the principal one; but on thickening the wire the eddy current is started, and the E.M.F. of induction, as measured by the sonometer at the terminals of the wire, diminishes at the same time that the resistance seems to increase. This is why Professor Hughes has not arrived at the same result as past theory would have led us to expect. He finds that the different wires, even without any magnetic properties, have different values of the counter electro-motive force. In the table which he has given us, so far as we are able to judge, the primary condition with very thin wires is a counter electro-motive force which varies inversely as the specific resistance. That is so because with a very thin wire, where practically the resistance of this go and return circuit is very great indeed, we have very little of that resistance to measure upon the bridge; that extra resistance of the variable period, and the whole of this electro-motive force of induction which is generated, is actually expended in the circuit, and is of the nature of an induced current such as is measurable by the sonometer. But when we come to greater diameters the case is very different, for after a time the resistance of the external circuit becomes diminished to such an enormous extent that the whole of this powerful electro-motive force induced at the central part of the wire is expended in coming round by the outside. Thus I was led to expect, from these theoretical grounds, not only

that Professor Hughes's statement was true, and that there was a maximum counter electro-motive force, as measured by the sonometer, for a certain diameter of the wire, but also that while the induction is diminishing it is sacrificing itself to this resistance; and therefore, while the induction is diminishing, the spurious resistance detected by Professor Hughes is increasing. Is not that so? I ask him the question because I believe I am right in stating that he found that when the induction effect, as measured by the sonometer, is diminished with increasing diameter, the variation in resistance is actually increased.

Professor HUGHES: Enormously.

Professor FORBES: Enormously. You will see that the diameter which regulates the maximum induction, as measured by the sonometer, is dependent upon the specific resistance, and the greater the resistance the greater will be the diameter, which corresponds with the maximum effect as shown on the sonometer. This explains completely and satisfactorily the difference in position of maximum between copper and brass. In Professor Hughes's chart the maxima are at different points of the line: brass actually cuts the line for copper, because it is a worse conductor, and requires a greater diameter to attain the same maximum sonometer effect. It would be tedious were I to go through the whole of these experiments—not only of these experiments, but of others which I have suggested to Professor Hughes, and which he has suggested to me in consequence of those suggestions, and a number of other experiments which he has carried out. It will be sufficient to say that when the explanation which I have offered occurred to me I went through the paper systematically, and I marked down seventeen different things which required to be explained. Then I went through the paper again to see whether these facts, combined with those which Lord Rayleigh has so clearly put before us, especially about the magnetic conditions and the completion of the magnetic circle (which is complete in solid but not in stranded wire), were explained by this hypothesis; and I find that every one of the experimental facts in the paper, and those which Professor Hughes has kindly undertaken and brought out since, are completely explained in that way.

Sir CHARLES BRIGHT: Gentlemen,—As the paper given us by Professor Hughes has, and naturally so, attracted so much attention; and seeing that we have had only three speakers discussing the subject to-night, while there are, I am quite sure, a great many members of the Society who would like to continue the subject, I would suggest that the discussion be now adjourned to the next meeting. I do not wish to delay coming papers which are of an interesting nature, but an adjournment seems desirable. Perhaps, however, before doing so, Dr. Hopkinson would like to make a few observations.

Dr. J. HOPKINSON: Two good methods of determining coefficients of self-induction were proposed by Maxwell; both depend on the Wheatstone bridge. The first is a null method, the coefficient being determined by comparison with a condenser of known capacity. The other, referred to by Lord Rayleigh, is a ballistic method, and is fully described in Professor Crystal's article in the "Encyclopædia Brittanica." It may make this method clearer to some if it is pointed out that the part of the experiment in which the balance of the resistance is disturbed has no other end than to determine the current given by the battery, and that this part can be omitted if a second galvanometer for measuring current be introduced into the circuit. In connection with the effects of self-induction, Lord Rayleigh touched upon the question of lightning conductors. A long time ago it was the opinion of those who dealt with lightning conductors that it was better to use a strip of copper than a copper rod of the same section, but for a considerable time this was thought to be an antiquated superstition; however, there is no doubt that, from a theoretical point of view at all events, it has a thoroughly sound basis. A strip of copper has less self-induction, considerably, than a round copper rod of the same section; and it is possible—but one has not data to work it out in numerical results—that the self-induction may be so great in a long copper rod, certainly in a long iron rod, that a disruptive discharge can be obtained from the upper part of the conductor to metal in its neighbourhood. I remember Sir William Thomson some time ago pointing that out to me as being an old superstition

which subsequent science had shown to have a thoroughly sound basis.

Mr. W. H. PREECE, on the invitation of the Chairman, said: I really think, Sir, that, as we have had such an interesting and instructive mathematical and theoretical evening, the practical remarks that I have to make, and some new facts that I have to bring forward, had better be deferred until next meeting, when the discussion will be resumed.

Sir CHARLES BRIGHT: That being the case, probably Mr. Preece will commence the discussion at our next meeting. This evening's discussion upon Professor Hughes's paper has been most instructive, and I am quite sure that it is by no means exhausted. I feel that a great many of us may have something to say upon points of the paper other than those touched upon to-night; especially seeing that the question involves the consideration of the best form of conductors of every kind, whether overground, submarine, or lightning conductors.

A ballot for new members then took place, at which the following candidates were elected:—

Members:

Henry T. Goodenough.	John Smith Raworth.

Associates:

Augustus Calder.	Percy Richardson Shill.
Arthur H. Dunning.	Lieut. Francis Henry Eldred Shipton, R.N.
John Leslie Fuller.	James N. Shorter.
Arthur J. L. Grimes.	Alan A. Campbell Swinton.
Walter Victor Morten.	Frederick Ward.
Ernest Edwin Putland.	

Students:

Percy Gilbert Ledger.	John Leyland Newland.
Herbert E. Mitchell.	Edward J. Wade.

The meeting then adjourned till 25th February, 1886.

The One Hundred and Fifty-second Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, February 25th, 1886—Professor D. E. HUGHES, F.R.S., President, in the Chair.

The minutes of the previous General Meeting were read and approved.

The names of new candidates were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Frank Bailey.
James Brand.
Bernard Drake.
Charles Thomas Fleetwood.
Lieut.-Col. A. C. Hamilton, R.E.
Col. R. Raynsford Jackson.
Charles F. de Kierzskowski-Steuart.
H. M. S. Matthews.
Joseph Bond Morgan.
Chas. Moseley.
Julius Sax.
J. E. Spagnoletti.
John Tasker.

The PRESIDENT: In accordance with the rules, I have to announce that Professor Ayrton, being so excessively engaged by other matters, has felt it necessary to resign his position as Chairman of the Editing Committee; and that the Council have appointed our Secretary, Mr. F. H. Webb, as Editor of the Society's Journal.

Donations to the Library were announced as having been received since the last meeting from the Director-General of Telegraphs in India; Royal Engineers' Institute; the Franklin Institute; Commandeur E. D'Amico, Foreign Member; Tadasuke Ishie, Foreign Member; Sir Frederick Abel, Past-President; A. R. Bennett, Member; J. A. Berly, Associate; Col. Sir Francis Bolton, Vice-President and Hon. Sec.; to whom the thanks of the meeting were unanimously accorded.

The PRESIDENT: The business of this evening being the further discussion upon my address, I beg leave to vacate the chair, and to ask our Past-President, Mr. C. E. Spagnoletti, to act as Chairman for the evening.

Mr. C. E. SPAGNOLETTI, Past-President, assumed the chair, and invited discussion upon Professor Hughes's paper, remarking that it was desirable that the speakers should be as concise as possible, so that the discussion might be concluded early, say by half-past nine o'clock, in order to give Professor Hughes time to reply to the various questions raised.

Lord RAYLEIGH (*communicated on Feb.* 24 *by*): In support of my statement that one reason, although probably not the principal one, why the resistance adjustment requires alteration in passing from the steady to the periodic currents, arises from the self-induction and resistance not being perfectly separated in the readings of Professor Hughes's apparatus, it may be desirable to communicate the results of a calculation applicable to the case where one only (P) of the four resistances, P, Q, R, S, has sensible self-induction (L).

Let M denote the (adjustable) coefficient of mutual induction between the coils in the battery and telephone branches; $\frac{p}{2\pi}$ the frequency of the vibration, supposed to be regular and to follow the harmonic law. Then the conditions of silence in the telephone are

$$\left.\begin{aligned} QR - SP &= p^2 ML \\ M(P + Q + R + S) &= SL \end{aligned}\right\}.$$

S is here the resistance opposite to P, and it will be seen that the ordinary resistance balance (S P = Q R) is departed from. The change here considered is peculiar to the apparatus, and, as far as its influence is concerned, it does not indicate a real alteration of resistance in the wire. Moreover, since p is involved, the disturbance depends upon the rapidity of vibration, so that, in the case of ordinary mixed sounds, silence can be attained only approximately. Again, from the second equation we see that M is not in general a correct measure of the value of L. If, however, P be very small, the desired condition of things is

approached; since by the construction of the apparatus $Q + R + S$ is constant (say W), and if P be small enough, S does not differ much from W, *i.e.*, most of the wire forming the three sides of the combination is devoted to the member opposite to P.

In the use of the apparatus, Professor Hughes makes Q and R nearly equal, so that $S = W - 2Q$. If we neglect the disturbance of the ordinary resistance balance, and write $SP = QR = Q^2$, we find

$$\frac{M}{L} = \frac{W + 2P - 2\sqrt{(PW + P^2)}}{W + P},$$

from which we may judge how small P must be in order that M may serve as a measure of L. For example, if P be very small, $M = L$; but if P were equal to W, M would be less than $\frac{1}{10}$ L. Good results require that P should not rise above $\frac{1}{20}$ W.

As mentioned at the beginning, I think it probable that there may be other causes producing a real and important change in the resistance when intermittent currents are used.

Mr. W. H. Preece: When Professor Hughes read his extremely valuable paper, he interpolated one or two remarks which made an impression upon me. He re-read a sentence, and said, "It is a very little sentence, but there is a very great deal in it." I think that applies to nearly every sentence in the paper. I do not suppose that we have ever had a paper brought before us that has formed such food for thought, and possessed such elements for discussion. The paper has the peculiar merit in it that it has brought to the knowledge of the many that which necessarily was possessed previously by but a few.

In the telegraph world, for many years past, self-induction in various forms has proved a *bête noire* which required all our knowledge and all our skill, not only to master, but to comprehend; for the effects of self-induction are invariably ill effects, and have various detrimental influences that require to be surmounted. In the year 1877 I had the pleasure of bringing before the Society the subject of self-induction in a paper that was most unfortunately titled "On Shunts." It was read in February, 1877, but, before it was printed and issued, the telephone was brought into this country, and monopolised the

attention of all of us, to the exclusion of either shunts or self-induction. But at that time I had devoted a great deal of attention to the subject: I investigated it experimentally, and endeavoured, to the best of my ability, to distinguish between those effects that are due to electro-static induction and those that are due to electro-magnetic induction. I pointed out how these effects of electro-magnetic induction, when they were applied to our apparatus, or to wires, introduced an effect that was exactly analogous to inertia in dynamics; and phenomena of self-induction, from that period, have by us been said to be the effects due to electro-magnetic inertia.

Now, in attacking this question, I am going to consider it, not from the mathematical point of view, but from that of energy. We know, from the days of Newton, that every action is always accompanied by an equal and opposite effect called "reaction;" and whenever in any system, of any sort or kind, energy in any shape or form is developed, then in some other part of that system energy is to an equal amount consumed. Now, whenever a current of electricity (and a current of electricity is simply one form of energy) is transmitted through a wire, the neighbourhood of that wire, and the wire itself, forms part of a magnetic field; and if in that magnetic field we have another wire, or a conductor of any sort or kind, energy appears in that conductor at the expense of the energy in the prime current. A magnetic field is of the nature of a spring in which we have action and reaction. When the stress arising from the flow of electricity ceases the field reacts, and the energy which was potential becomes again kinetic; little or none is lost. It appears usually in the form of sparks, and all our knowledge of electro-magnetic inertia in this shape was known and experienced by physical shocks received by the system. Faraday went most thoroughly and completely into the subject, and his researches are replete with information on this point. There were two French scientists—Fizeau and Gounelle—who, although they did not deal with this question of electro-magnetic inertia, pointed out that the speed of electricity through a copper wire, as compared with its speed through an iron wire, was as 180:100; in other words, they found that

electricity travelled through copper at the rate of 180,000 kilomètres per second, while in the case of iron it travelled at the rate of 100,000 kilomètres per second. An Italian scientist—Villari—also touched on this question, and showed, as Professor Hughes has shown, that when resistance is measured by rapid intermittent currents, the resistance of iron differs very considerably when it is measured with a steady current to what it is when measured with rapid reversals; and without, probably, knowing so much of the subject as we now know, he attributed this false resistance to its true cause, viz., to the fact that the iron itself was magnetised and demagnetised. All this has been made perfectly clear to us by Professor Hughes in the way that was so nicely brought before us on a previous occasion. But in 1877 I examined this question not so much to determine what took place in straight wires as what took place in the various forms of apparatus connected to those wires. We had not then an instrument at all approaching the delicate and beautiful one of Professor Hughes. A Thomson reflecting galvanometer was used in the experiments [*Fig.* 1]. Before it was possible to make the reflecting

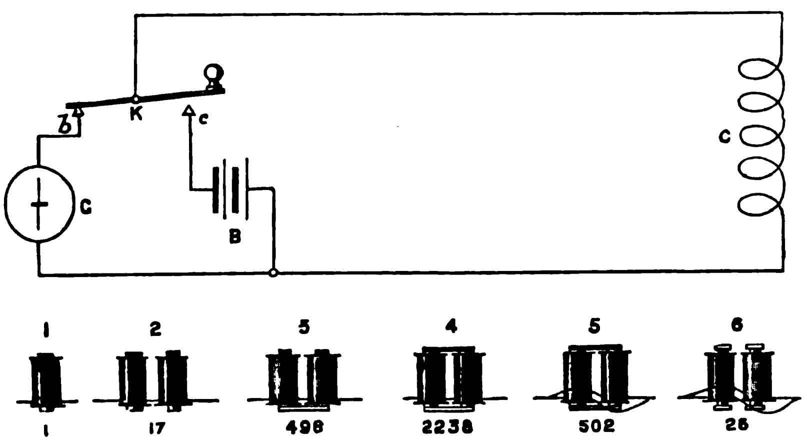


Fig. 1.

galvanometer, G, responsive to the quantitative effects of electro-magnetic inertia, it was necessary to start with a unit coil upon which the measurements could be based. One end of the coil, *c*, was placed in connection with a key, K, which rested on a back

contact, *b*, in connection with the reflecting galvanometer; the front contact, *c*, of the key being in connection with a battery, B: the circuit was formed through the coil C. When the key was depressed a current passed through the coil and magnetised it, or, as the Americans are very fond of expressing, "energised" it. When the key flew back to its contact, then, if there were any inductive effect, either electro-static or electro-magnetic, the current would flow back through the galvanometer and make a deflection. The current of an ordinary relay coil (1) was taken as the unit, or 1. Then a second and similar coil (2) was laid alongside it; iron cores were put inside; the coils were connected in series, and the effect upon the galvanometer was 17 times greater than the effect produced by the unit coil. A yoke, or piece of iron, was introduced so as to make the coils form an ordinary electro-magnet (3), and the effect then produced on the galvanometer was 496 times greater than that of the unit coil; the addition of a second piece of iron, representing the armature (4), increased the inductive effect to 2,238 times that of the unit coil. So that the mere formation of an electro-magnetic circuit such as exists in relays, or magnets when the armature is attracted, increases the self-induction of the system from 1 to 2,238. The effect was then tried of connecting up the coils in "quantity" (5). When the current was divided by four, one half went to one coil, the other half to the other coil; and that arrangement, just as was expected, brought down the effect to one-fourth of what it was before—one-fourth, because in each coil there is only half the electro-motive force due to one-half the current passing through it. The result showed the effect of self-induction to be very much greater than anybody could possibly have foreseen until it was tried experimentally. Having got so far, various relays were tried, and they were found to vary within extraordinary limits: one, very well known and much used, gave 1,688; another gave 279; and another only 26. The great falling off from 1,688 to 26 was simply due to the fact that the magnetic circuit was cut at the top and bottom (6); the mere breaking of a circuit up into two parts reduced the self-induction down from 2,238 until it came

to 26, which is the effect of the form of relay now generally used in the telegraphs, and in which, from that very simple application of a fact discovered by experiment, self-induction has been almost entirely eliminated. Now the effect of these phenomena, in the case of the telegraphs, is simply a reduction in the speed of working, and with such a relay as that giving a self-induction represented by 1,688 it was not possible to work at more than about 50 or 60 words a minute; whereas with the one whose self-induction is only 26 it has been possible to work at the rate of 400 words a minute, and even 450 has been attained.

Again, in the case of telephones, the effect of the self-induction has been to increase these difficulties that check clear articulation. If all the effects of self-induction can be removed from a wire, conversation to any distance becomes a matter of great ease; but the true reason why speaking to a distance is so difficult is the presence of this electro-magnetic inertia, more than to the effect of electro-static induction.

As to the remedies. I pointed out that in the case of the relay the remedy is very simple. In the case of open wires, such as Professor Hughes has dealt with, the remedy is forming a metallic circuit, and practically doubling the wire upon itself; but, as Professor Hughes has also pointed out, an additional effect is obtained if the metallic circuit be also twisted, by which arrangement all the effects of electro-magnetic induction from contiguous wires are remedied. In the Post Office we tried a rather expensive experiment; in fact, during the past year we have tried two very expensive experiments. One experiment was the erection of a wire from London to Newcastle-on-Tyne—a distance of 278 miles—in order to test the relative merit of copper and iron, and I venture to think that to the success of that experiment we are indebted to the subject having been brought before this Society.

The rate of working of Wheatstone apparatus was improved 12½ per cent. 414 words per minute were obtained, and a careful experiment on the number of reversals which could be sent per second gave the following result:—

Copper	167
Iron	120

I was a little alarmed by a statement in the paper that the field expended itself in the interior of iron wires, but in the exterior of copper wires. If this were true, then it might happen that the external field of a copper wire would be more powerful than that of iron, and therefore disturbances from contiguous wires would increase with copper. This would have been a serious objection to copper. I therefore tested the point experimentally [*Fig.* 2]. An iron wire (No. 16 gauge), I, and

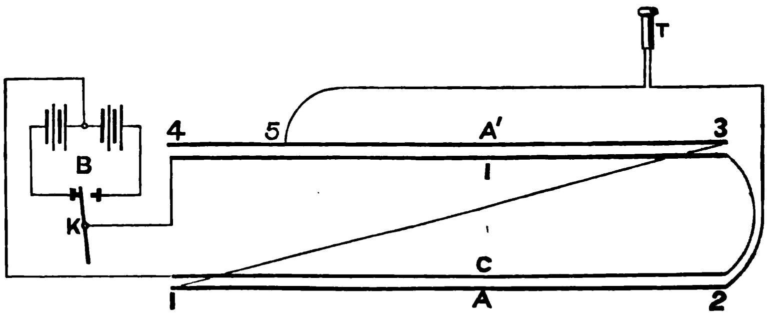


FIG. 2.

a copper wire, C, of the same gauge were fixed to boards 5 ft. long, and very close to each of them similar copper wires, A, A^1, were fixed. A current from a battery, B, was intermittently and rapidly reversed through the circuit I C. A telephone, T, was connected in a bridge. When this bridge was connected to 2 and 3, the whole inductive effect of the copper was heard. If it were connected to 1 and 4 the whole effect of the iron would be heard. Now, if the inductive effect of the copper were the same as that of the iron, then when the bridge was at 4 and 2 there would be silence, or neutrality. But it was not so; and it was only when the bridge was at 5 and 2 that zero was found, which shows that the inductive effect of iron is to that of copper 1·33 : 1, and that copper is therefore superior to iron in this respect also.

The second experiment was of a more costly character, and it was a failure, and that was: Four wires were erected between London, Manchester, and Liverpool, for the purpose of testing the distance to which telephones could be applied; and I am sorry to say that it was found quite impossible to

speak between London and Manchester, or between London and Liverpool, and I was very much disappointed. The wires were twisted, they were the very best wires that we could erect, they were insulated in the very best fashion, but speaking was blurred and sounds were obliterated by that effect that we all know now, thanks to Professor Hughes, to be an effect due to self-induction. These wires were iron, but had they been copper I have every reason to think that the result would have been different.

It is certainly possible to reduce, if not to eliminate, as Professor Hughes has shown, the deleterious effects he has brought out; and this I take to be the principal discovery, the main feature, of his paper. He has shown that in straight wires the effect of self-induction can be cured by stranding up the wire if it be of iron. He has given us facts in his paper; he has shown experiments before us that are almost convincing—I say almost, because I myself am not quite convinced. Professor Hughes told us the other evening that he was very anxious to convince us all, but at the present moment I am one of those who will not acknowledge being quite convinced that the result is as Professor Hughes shows it to be. There is no doubt that to strand up an iron wire will very considerably diminish the effects of self-induction, because it limits the magnetic field; but supposing that it were possible—and I do not say that it is not—to entirely eliminate from iron the effects of self-induction by stranding it up, then I say that the practical advantage of that discovery will be very small, because, in the first place, in stranding up iron wire you do not diminish the resistance of the wire, and resistance is a very material element in speed of working; in the next place, the very form of a stranded wire is conducive to the collection of snow upon it, and snow, although it comes upon us very rarely, when it does come, acts upon stranded wires the most, from the better accumulating surface which they present. Curiously enough, snowstorms recur at periods of ten years. In 1866 we had a tremendous snowstorm; in 1876 another; recently, in 1886, we have had another. I hope we shall be another ten years before we have such a disastrous snowstorm as that of 1886. The electro-static capacity of a stranded wire, again, is greater

than that of a solid cylindrical wire; it varies from 5 to 10 per cent. greater for the same resistance. But, above all, a stranded wire is not so durable as a copper wire: moisture accumulates in the interstices. For these four reasons—high resistance, bad form, high capacity, and small durability—however perfect a stranded wire may be, I do not think that it is at all likely that we shall use it in preference to copper. The influence of copper is simply marvellous. I have sent to Professor Hughes some specimens of compound wire, and I will leave him to narrate the experiments that he has made upon them. He shows unmistakably that a copper envelope to a steel wire acts as a shunt, and removes, or diminishes very largely, the effects of self-induction.

There is another way of eliminating self-induction that we employ in the Post Office to a very considerable extent; in fact, at the present moment nearly all the important circuits of this country—those that work at high speed, and which suffer from self-induction—are virtually cured by another process altogether. The arrangement [*see Fig.* 3] is such that the two coils of a

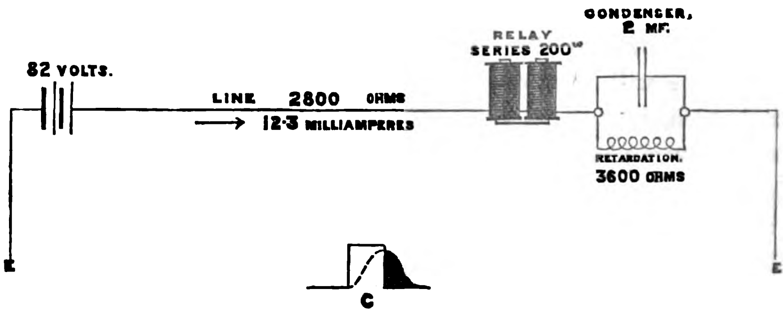


FIG. 3.

relay upon a wire between, say, London and Glasgow are connected up in "quantity;" the relay is connected to earth through a condenser, which breaks the circuit and would stop the communication, but it is bridged over by a resistance. If a current arrives at the distant end of the circuit, entirely free from any self-induction, then, if we represent the strength of current by an ordinate, and let the duration of it be the abscissa, the current arriving at the distant end would have a form as I have shown [C]. It would rise instantly to its maximum strength;

the moment the circuit was broken it would fall down to zero. But the effect of self-induction, and the effect of electro-static induction, and all the other disturbances—and they are numerous—in connection with the working of telegraphs, convert the current into a current of different form [*dotted curve*]. If these currents follow each other in great rapidity, their alteration of form represents the rate at which they flow through, and the great object is to hasten their flow through so as to cut off that portion [*shaded*] of the current; now that is done by the insertion of the condenser. [*The arrival of the current and the action of the condenser in circuit were described in detail.*]

The resistance in circuit is such that it can be made to adjust the current to just the amount required to charge the condenser, so that when the circuit is broken the condenser is discharged, partly through the shunt and partly through the line; and thus we are enabled to send in a second as many currents through the line as could be sent were there practically no self-induction at all.

As to sparking. Sparking is an effect which is not only to be found in dynamos, but one that we suffer very much indeed from in telegraphic apparatus. The self-induction of a long straight wire without any apparatus upon it gives that effect which results in the disintegration of the points of contact; but if electro-magnetic apparatus be present the effect is greatly magnified. Small arcs are formed that we call sparks; the points of contact disintegrate and become dirty, and cause a good deal of trouble. No end of schemes have been suggested at different times to cure this, and it was only, I think, within the last two years that we came to the conclusion that the cause of this sparking was self-induction. We have in England a practice which is peculiar to our telegraphs; that is, in every circuit we have a galvanometer. We always like to see what is going on: we like to see that our current is going out, or that it is coming in. Everything was removed from our circuits to try to cure sparking, except the galvanometer. At last it struck one of our wise young telegraphists in Bristol that probably the cause of sparking was in this galvanometer itself, and he simply short-circuited the

galvanometer, when at once all sparking disappeared, and one source of disturbance from self-induction was eliminated.

Mr. Pope, in the few capital practical remarks he made the other evening, stated that he had often heard that the effect of connecting up the coils or a relay in multiple arc, or in parallel—we call it in "quantity"—had the effect of expediting the rate of working, and he never could thoroughly understand why. In my paper of 1877 I explained the reason why, which I am happy to say is exactly the same explanation as that given by Professor Hughes. The reason why coils joined up in multiple arc work quicker than those joined up in series is because self-induction is eliminated by a shunt action. When two coils are joined up in quantity, the counter electro-motive force set up in one coil, going in one direction, is neutralised by that set up in the other coil, going in the opposite direction, and so the effect of electro-magnetic inertia is removed from the telegraphic apparatus.

The results of Professor Hughes have carried us far beyond the mere elementary results that I have brought before you. Mine have been applied to apparatus; his have been applied to straight wires; and the most curious thing is this, that while it took me 278 miles of wire to find out that there was any difference between copper and iron, Professor Hughes was able to show us exactly the same result with only ten inches. This illustrates, not only the exactitude, skill, and instinct of the experimenter, but the marvellous delicacy of the apparatus that he uses. He has shown us, not only that self-induction varies with the form of conductors, but he has also shown us that it varies with its physical condition; and I doubt whether, unless those who have had the paper have read it with great care, sufficient attention has been paid to that portion where Professor Hughes has shown that the action of heat alone has also removed the effects of self-induction. These effects, and his paper, show how our science of electricity has been enriched by practice. Theories always come after the event. I do not know any theory, not even Clerk-Maxwell's theory, that would have predicated what we have seen brought before our

Society. There is nobody who has placed in the hands of us practical men such splendid apparatus, such useful tools with which to peer into the internals of matter, as Professor Hughes has done, not only in this paper, but in other papers that we have listened to with so much pleasure and delight.

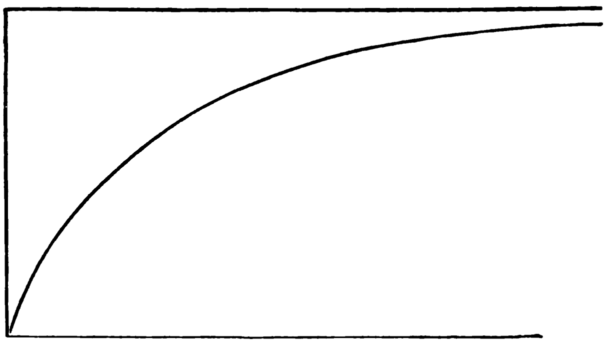
Dr. J. A. Fleming: The great service Professor Hughes, Sir, has done us in his address, is to direct our thoughts, both as theorists and as practists, to the conditions and phenomena of electric flow when in a state of fluctuation. The greater simplicity of problems of steady flow, and the wider practical applications of continuous currents, serve to keep many of us down in a low level of thought—in a kind of valley populated chiefly by ohms and volts; but Professor Hughes has lifted us up to a higher level of thought, and shown us from the summit of his interesting researches a more varied and lovely prospect, in which the chief object in the landscape is not mere ohmic resistance, but electrokinetic momentum; and the suggestive lines of thought thus opened up to us must make many desirous of exploring these pastures new. One or two remarks I should like to make on the theory of the subject. In the first place, care must be taken that the phrases "steady" and "variable" state of the current are properly understood. Truly speaking, there is no such thing as a steady current. Consider for a moment the operation of starting a current in a wire. In addition to the passive or ohmic resistance of the wire, we know that we have to supply energy, which is in some way or other absorbed by the medium round the wire, or taken up in the wire by a property analogous to the *vis inertiæ* of matter; and we call that quantity by which we have to multiply half the square of the current strength to obtain a numerical measure of the energy so absorbed, the "coefficient of self-induction." Now, writing the equation of activity for a current running in a conductor, we have

$$E\,i = R\,i^2 + \frac{d}{d\,t}\left(\tfrac{1}{2}\,L\,i^2\right),$$

where E is the electro-motive force (supposed constant), and R the ohmic resistance of the wire, and i the current at instant t. Integrating this, we have the well-known result—

$$i = \frac{E}{R}\left(1 - e^{-\frac{R}{L}t}\right).$$

I have drawn here a diagram which represents graphically the equation, and shows us the gradual formation of a current in a wire for certain assumed constants.



I have supposed an electro-motive force of one volt to act on a conductor whose resistance is $\frac{1}{10}$ ohm, and which has a coefficient of self-induction of ·43 × 10 cm. This is, perhaps, a case impossible to realise in practice, but it serves as an illustration. Now this curve shows us that in such a conductor the given E.M.F. would tend to make a current approximating after an infinite time to 10 ampères. At the end of one second from applying the E.M.F., the current would be ·9 of this; at the end of two seconds, ·99 of 10 ampères; and so on; but, however long the E.M.F. was applied, the current would never reach the value assigned to it by Ohm's law. What is true in this case is true in every other. There is no one point where we can say the current ceases to be variable and becomes steady. All we can say is that after a time, sometimes exceedingly short, the variation ceases to be observable by our instruments. Now, if we transform the current equation into

$$\log. \frac{I}{I-i} = \frac{R}{L}\,t, \text{ where } I = \frac{E}{R},$$

and is therefore the maximum current, we see that if, instead of plotting time and current as ordinates, we plot time and difference between logarithm of full current and the logarithm of the amount by which the current falls short at any instant of

full current, we get a straight line. Now the co-tangent of the slope of this line is the ratio of L to R, or self-induction to ohmic resistance, and this is the time constant of the conductor.

Consider the case where $i = \frac{e-1}{e}$ of I, where $e = 2{\cdot}71828$; that is, where the actual current is about $\frac{17}{27}$ of the the maximum current. For this value of i we have $t = \frac{L}{R}$; or the time when the current has reached this fraction of the maximum is the time constant. Now the time constant has this important property, that multiplying the time constant by the resistance of the wire gives us at once the coefficient of self-induction. Although, therefore, there is no sharply marked point of division between the steady and the variable state, it does seem to be important to obtain, if possible, an experimental method of determining the time constant of a coil or conductor. Turning now to the interesting experiments with the self-induction balance. I looked at these results with especial interest to see how they fitted in with the theory of Maxwell. Maxwell has given an expression for the self-induction of round wires which is of the form

$$A + B\,\mu - \log.\,\rho + \log.\,R,$$

where μ, ρ, and R are the magnetic permeability, specific resistance, and total resistance of the wire, and A and B are constants depending on the form of the circuit. Now, if we may make the assumption that in Professor Hughes's experiments the average current through the wire under test was expressible in the form $\frac{I\,T}{p}$; then if the average deficit from full current $= i$,

$$i = I\left(1 - \frac{T}{p}\right),$$

where I is the maximum current, T the time constant, and p a constant depending on the interruptions, then it is not difficult to show that the conditions for a maximum electro-motive force lead us to an equation for R of the form

$$R - \log.\,R = C + \mu - \log.\,\rho;$$

showing that for great permeability the maximum diameter, or

diameter corresponding to maximum electro-motive force, will be small, and that if μ is constant, then the diameter will increase with the specific resistance. Now this is just what Professor Hughes find. The order in which he places the metals in his table is, for the non-magnetic metals, the order of their conductivity; and the magnetic metals head the list in the order of their permeability for low magnetising forces. Professor Hughes does not give cast iron in his list, but we might anticipate whereabouts it will come.

I take it that the explanation of Professor Hughes's valuable discovery with regard to the stranded iron cable is to be explained thus:—The permeability which must be considered in these equations is the permeability in a circular direction round the wire. Anything, therefore, which reduces this will diminish the self-induction. Might I ask Professor Hughes if he has tried a fluted iron rod, and compared it with a circular rod of same cross sectional area? With regard to the question of the resistance of a conductor during the so-called variable stage of a conductor, it is easy to see that this resistance at any instant is expressed by a function of the form

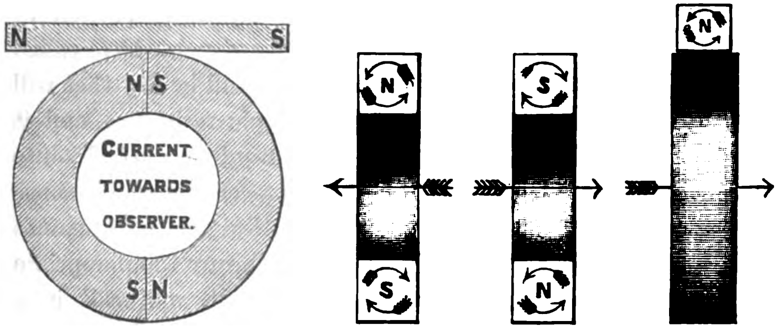
$$\frac{R}{1 - e^{-\frac{R}{L}t}}, \quad \text{or} \quad \frac{R}{1 - e^{-\frac{t}{T}}}$$

where R is the ohmic resistance for steady currents, and t is the time which has elapsed since the application of the fixed electro-motive force E to a conductor whose time constant is T. In a paper on "Networks of Conductors" I have pointed out the fact that the resistance of a galvanometer is by no means a constant, but is a function of the time from the beginning of the charge through it. If a condenser is discharged through a galvanometer, the effective resistance of the galvanometer is greater during the first period of the discharge, and less during the final part of the discharge, than it is when measured with a steady current; and accordingly the division of current amongst conductors having perceptible coefficients of induction is governed largely by the time constant of each.

In conclusion, I would venture, with diffidence, to make one

suggestion. It is abundantly evident that, in proportion as alternate currents become studied, the quantity we have called the "coefficient of self-induction" of a wire will be one that will be seen to be of equal importance with ohmic resistance, and it would be convenient to have one short word for 10^9 absolute units of self-induction. Following the precedents which cause us now to select as the names of our practical units the names of distinguished discoverers, might we not venture to appropriate for this purpose the name of our President, and call it a "hughes"? And, if he will not disclaim having a fresh little unit christened after him, we shall not only be the gainers by a convenient word, but we shall add a link of association between it and a presidential address which must ever stand high in interest amongst the number of those which have been delivered within these walls.

Mr. Desmond G. Fitzgerald: The observations that have been made in the discussion on Professor Hughes's very valuable paper have confirmed me very strongly in the notion that more especially the variable period which precedes the normal current is deserving of further study and greater observation than it has hitherto obtained. The "extra-current" period which follows upon the breaking of the circuit is perhaps better understood. I am confirmed in this view by the continued use of the expression, "the induction of a current on itself," in reference to the former period. I think it can be shown that electro-magnetic induction *precedes* the passage of a current, and that this expression, which is old, ought also to be considered as obsolete. Another important point is, I think, that these effects—said to be due to self-induction or electro-magnetic inertia—are probably solely dependent upon the electro-magnetic capacity of the conductor, or, rather, of the circuit; and we have no reason, so far as I know, to consider that any other cause is in action. In the *Electrical Review* of August 18th, 1870, I gave the result of an investigation into the magnetic polarity of a conductor conveying a current. This polarity may be quite familiar to some, but I have reason to believe that it is by no means familiar to everybody; and therefore, with your permission, Mr. President, I will draw the diagram I then gave.



Every conductor conveying a current is found to possess in greater or less degree, according to the nature of the conductor, as well as the magnitude of the current, the polarity here represented. Now, if I were to state that the soft iron core of an electro-magnet becomes magnetised by the passage of a current through the coils, I should probably not be contradicted by anybody here. Mr. Preece has made such a statement this evening, and I do not suppose that anyone was disposed to contradict him. But I say that there is reason to think that the production of the magnetism in the conductor, and in the electro-magnet surrounded by its coils, *precedes* the passage of the current; and if this be the case, it points to an extremely interesting and neglected field of research. When we pass a current through the coils of an electro-magnet we virtually insert a magnet within the coils of that electro-magnet, the polarity of the magnet being such that the current it would induce would oppose the passage of a current such as would generate the magnetism. There seems, therefore, clearly to be, during this period which precedes the normal passage of a current, some short period of time during which there is an absence of current. The question then arises, Is the battery at work during this period? If so, we have this extraordinary thing to consider and to observe: we have a battery at work, and yet we have no indication by the galvanometer of the passage of any current through the circuit. It is familiar to most of you, no doubt, that in a circuit of great electro-magnetic inertia there is no sign of the passage of a current for an appreciable period—appreciable even by the eye—after the completion of the circuit.

It is during this interesting period, apparently, that magnetism is born. We are present at the birth cf magnetism when we depress a key to complete a circuit of great electro-magnetic inertia; and I feel sure that Professor Hughes, who has already so strong a grip of the physics of magnetism, will still further enlighten us if he pursues this clue. If, on the other hand, the battery is, as we might suppose, idle during this period when no current is visible in the circuit, then arises the interesting question, which I have myself never been able to satisfactorily answer, Whence is the energy derived—the very considerable quantity of energy—which becomes stored up as electro-magnetic energy in a circuit, say, including a great number of electro-magnets? I myself am inclined to hold, with most people, that during the period which precedes the normal passage of the current the battery is idle, or nearly so. Now there is apparently no available source of energy other than the battery; but whence, I say, is derived the work which is stored up as electro-magnetic energy? This is a most interesting problem, and one which I should be glad to see satisfactorily solved. Possibly some portion of the energy existing as heat in the circuit may disappear; and in this variable period which precedes the passage of the normal current we might, if we could devise instruments sufficiently sensitive, observe the production of cold, as in the period which follows upon the interruption of the normal current we might observe a more than corresponding development of heat.

I had a great deal more to say, particularly as to the instantaneous passage of the current of static charge, the molecular theory of conduction, and the production—which I investigated in 1868—of an elementary magnet by the rotation of a static charge; but as time is so limited, and as I have had to interrupt the order of my notes, I think I will defer any further observations until another opportunity.

Professor SILVANUS P. THOMPSON: I have, Sir, a few remarks to make, some of them of a theoretical nature, together with some deductions of a more practical kind. I have seldom heard with greater pleasure any scientific paper read than the paper

which Professor Hughes gave us as his presidential address. The enormous amount of detail in the experiments he explained, especially of detail requiring thought to understand, is something very remarkable indeed. It has occurred to me that there is one point on which we ought to be a little more clear in arguing about Professor Hughes's experiments. It is this—that we should take into account, in considering this question of the apparent resistance offered by conductors possessing self-induction, the rate at which the current is being made to vary. I have looked rather carefully through Professor Hughes's paper, and I am rather hoping that he will have something presently to say to us in further explanation of this point. He mentions particularly that the rate of interruption of the current by the clock microphone might be anything between (if I remember rightly) 10 and 100 per second. I want to know, if I am not inquiring too closely into the secrets of the experimenting-room, at which of these speeds the particular experimental results were obtained that are plotted out in the various curves shown in the paper. Further, was any difference observed in the case where a high speed of interruption was used, compared with that where a low speed of interruption was used? I ask the question because the practical points that I wish to bring out from the theoretical ones depend upon the rate at which these variations of the current take place or are made to succeed one another. I am not going, by any means, to say that Professor Hughes's mode of experimenting is not perfect; indeed, it is seldom, I think, that a more perfect instrument of its kind has ever been produced to a scientific audience; but I should like to know what would happen if, instead of using the clock microphone—which produces interruptions of a somewhat irregular kind, impossible easily to express in an adequate mathematical form—something more like a musical tone were introduced by a harmonic interruptor. I mean by this something which would send electric undulations of a truly harmonic character, having a definite known period—say, for instance, exactly 100 waves a second, or exactly 400 waves a second—corresponding to some recognisable musical note. I am inclined to think, if Professor Hughes does not mind my

making a suggestion to him, that in some of the cases in which he does not get a really complete balance and silence in the telephone, he would be much more likely to obtain such a result if the interruption that was going on was a simple harmonic one, and did not consist of clicks, short and sharp, or more or less prolonged, according to the elasticity of the spring that makes them by hopping from one tooth of the wheel to the next. The way in which I want to treat this matter is to take the case where a pure musical note creates the variations of the current, so that the varying electromotive force thrown into the circuit should be represented mathematically by some such formula as

$$E_t = E_o \sin \theta,$$

where E_t represents the electromotive force at the lapse of a certain time (t), E_o the maximum electromotive force, and θ the angle that corresponds, on the circle of reference, to the time that has elapsed since the origin, and therefore equal to $2 \pi n t$, where n is the number of vibrations per second. Were there no self-induction, we should, of course, write for the current at the time t,

$$i_t = \frac{E_t}{R},$$

or

$$i_t = \frac{E_o}{R} \sin \theta,$$

where R is the number of ohms of resistance. But if there is self-induction as well as resistance in the circuit, then the expression for the current must no longer be written in that simple way. Ohm's law, we may say, is no longer adequate, except in a modified sense, because the self-induction comes in and alters the fluctuations of the current and makes them lag behind those of the electromotive force, retarding them in phase and diminishing them in amplitude. I will not go through the stages whereby the equation is obtained, but it is well known, at any rate to those who work with alternate-current machines, as well as to those who have worked on the problem of the transmission of harmonic interruptions—that is to say, of musical notes—by telephone.

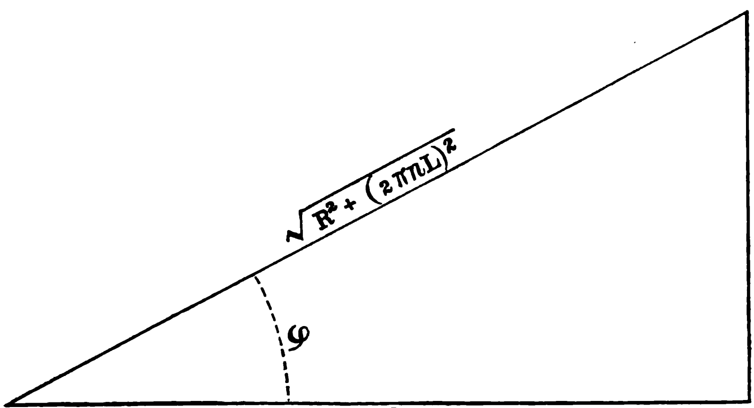
What we have to write is this—

$$i_t = \frac{E_o}{\sqrt{R^2 + (2\,\pi\,n\,L)^2}} \sin(\theta - \phi),$$

where L stands for the coefficient of self-induction, and ϕ is the angle of retardation, and is such that its tangent is equal to the ratio between $2\,\pi\,n$ L and R, or

$$\tan\phi = \frac{2\,\pi\,n\,L}{R}.$$

We see from this long formula that the current is no longer expressed as a simple electro-motive force divided by a simple resistance. The denominator, instead of being merely the ohms of resistance, is a complex quantity which we may briefly call the "apparent resistance," and which is greater than the actual number of ohms. The important fact that self-induction causes an additional or spurious resistance to the true or ohmic resistance of the armatures of dynamo machines was pointed out with great emphasis by my friends and colleagues Professors Ayrton and Perry in their paper on electro-motors. I want now to show how we can write this spurious resistance graphically in a very simple manner. Suppose we take the real resistance (R) and mark it out as a straight line representing so many ohms, to scale.



Then, if we take the ohm as unit of resistance, we must for our unit of self-induction take the corresponding unit—the "hughes" —which, since the ohm is 10^9, will, I suppose, be one ohm-second, or 10^9 centimètres. Expressing L, therefore, in "hughes"es,

multiply by $2\pi n$, and plot out $2\pi n L$ on the same scale at right angles to R. Then the sloping hypothenuse which joins the ends of these lines will represent $\sqrt{R^2 + (2\pi n L)^2}$, the effective resistance. R is the real resistance; $2\pi n L$ is what Professors Ayrton and Perry call the "spurious resistance." I am not, indeed, quite sure whether they do call this the "spurious resistance," or whether they give that name to the difference between the real and the apparent resistance—the latter would, I think, be more appropriate—but, in any case, whether we are dealing with an alternate-current dynamo, or with the sections of the coil of armature of a direct-current dynamo, with an induction coil, with the coil of a telephone receiver, or with a whole telephone circuit, we have to deal with a spurious resistance which comes in to make the apparent resistance greater than the real resistance. It may further be pointed out that the diagram which I have sketched affords a geometrical illustration of the retardation-term ϕ, because the ratio which stands for the tangent of ϕ is nothing else than the slope of the hypothenuse of our diagram. It is at once evident from the diagram that any increase in either n or L—either in the rapidity of the interruptions or in the actual coefficient of self-induction—will alter our diagram, increasing both the apparent resistance as represented by the *length* of the hypothenuse, and the retardation of phase as represented by its angle of *slope*. Now the point I have to put to Professor Hughes is this: If the interruptions are irregular, there will be a mixture of effects, because there will be a constantly varying length to the line $2\pi n L$; whereas, if the interruptions are those of a pure note (and harmonic in character), consisting of n vibrations per second, the length of the line $2\pi n L$ will be definite. Further, if experiments are made with a certain frequency of interruption (n), and then other experiments are made, say with twice as many vibrations per second, there should in the latter case (our triangle being now doubled in height) be both a greater apparent resistance and a greater retardation of phase. If I understand Professor Hughes's experiments rightly, he first arranges his bridge (with steady currents) to balance the true resistance, R; and then, switching the clock

microphone into the battery circuit, he attempts to balance the apparent resistance, $\sqrt{R^2 + (2\pi n L)^2}$, which he finds always to be greater. He then finds that he does not get silence—only a minimum of sound—in the telephone; that is, of course, because, having more self-induction in one half of his bridge than in the other, the retardation of phase in the electric waves which are passing through the arm in which there is self-induction prevents there being any point, on the one half of the bridge, at which the rise and fall of potential will be exactly both simultaneous in time as well as equal in amount with that of any given point on the other half of the bridge. There is therefore always *some* rise and fall of potential between the ends of the bridging telephone circuit, and it is to silence this that Professor Hughes applies the beautiful sonometer to introduce enough induced current to balance the effect; the amount of "induction" so brought in to balance being approximately a measure of the amount of retardation, and therefore (in my diagram) proportional to the slope of the hypothenuse. The idea is a most beautiful one, and would give perfect silence if the waves set up in the telephone circuit by the difference in the times of the waves in the two halves of the bridge did not themselves differ in phase from the balancing waves introduced through the sonometer. Unfortunately, the waves arising from the *difference* between the retarded and non-retarded waves in the two halves of the bridge can never differ by so much as one-quarter of a wave-period from the phase of the original waves, whilst those introduced by induction through the sonometer will differ by almost an exact quarter of a wave-period. Hence the silence will not be complete in any case, though a minimum of sound may be reached.

I am now able to apply my argument to one of the most interesting points of Professor Hughes's paper, viz., the differences which he finds between non-magnetic metals, such as copper and brass. These differences were emphasised last meeting by Professor Forbes, who explained them by a very remarkable argument, to which I listened carefully, but which, I must confess, I am unable to follow in its entirety. He maintained, if I followed him aright, that up the inside of a stout cylindrical

conductor there passed a self-induced current in opposition to the main current; and he based upon this supposition an explanation of the difference in behaviour of copper and brass. Now I am perfectly aware that in the case of a solid circular conductor the current, when first turned on, and when it is rising in strength, rises in the outside before the inside; and that is accounted for by the counter electromotive force of self-induction in the interior of the solid conductor. But I cannot follow the argument by which he sought to prove that the secondary counter electromotive force in a straight conductor will be greater than the primary electromotive force. I cannot but think that the proof Professor Forbes described has got some little fallacy lurking at the bottom of it. I gathered that Professor Forbes was driven to this curious theory because he could not otherwise explain Professor Hughes's result that, using two metals neither of which was magnetic, such as copper and brass, the two effects which have to be balanced varied in opposite senses. The case may be thus stated: Suppose a piece of copper wire has been tested on the bridge with the steady current, it will be found necessary when balancing with the fluctuating currents to introduce a certain apparent increase in the balancing resistance, and to introduce also a certain amount of balancing induction. Then, when a brass wire of the same length and thickness is substituted, it is found that, though the apparent resistance is greater than before, there must be a less amount of balancing induction introduced. At first sight it is certainly curious that we should find one of these effects to increase while the other diminishes; but it certainly does not require the hypothesis of Professor Forbes to explain the circumstance. It is explained completely by the equation. Apply it to test what is the result of having two wires—one of copper, the other of brass—of the same form, the same length, the same cross section, the same magnetic inductive capacity (the same as air), but differing only in resistance. So far as both the geometry and the magnetic properties of the materials are concerned, L will be a constant. The wires will differ only in resistance. Well, in our formula, if L is constant and R is variable, you will see that by increasing

the real resistance (by using brass instead of copper) both the apparent resistance and the retardation of phase will be altered. If L is constant, then the height of our triangle $2\pi n L$ will remain constant. Under these circumstances, if R is increased, the triangle will be elongated, the hypothenuse will be longer, and will also be inclined at a more gentle slope; that is to say, an increase of the real resistance has the effect of *increasing* the apparent resistance, but of *decreasing* the retardation of phase. That, I think, entirely explains the observed facts without having recourse to the very difficult suggestion set before us by Professor Forbes.

This equation will also help us in considering the practical problems of the construction of telephonic apparatus and telephone circuits. Before dealing with these matters, I wish to say that I entirely appreciate the remarks of Professor Fleming in regard to the diminution of self-induction in the stranded iron wires being due to the interruptions of the circular continuity of the periphery; and I entirely endorse the supposition that a wire, such as a pinion or grooved wire, would certainly diminish the self-induction, provided the cross section remained the same. But that argument, which holds good for iron wire, fails when applied to copper, because the magnetic permeability of a non-magnetic wire is the same as air, and nothing is gained in that respect by breaking up the periphery. But there is the advantage that, while the same cross section is preserved, you have diminished that quantity which must always be taken into account in considering the self-induction of a single conductor, viz., the geometric mean distance of each part from every other part. Increase the average distance of each portion of cross section from the centre, and you diminish the self-induction. In fact, the geometric mean distance in the cross section is the key to the whole of Professor Hughes's experiments on the influence of sectional area. But while I endorse on this ground the advantage of a stellate form of cross section, I would ask Professor Fleming whether he has ever heard of a rather unfortunate body—which, I believe, rejoiced in the name of the "Spiral Wire Syndicate"—which proposed to set up telephone wires made with a spiral groove. Such a company was formed, but

I am afraid that it failed from want of appreciation on the part of the public of the importance in self-induction of the geometric mean distance of the cross section.

I am sure Mr. Preece will pardon me if I venture to think that the effect of iron wires in retarding rapid working was rather better known than his remarks would lead one to suppose. It is not more than three or four years ago that I made a report to a certain telephone company as to the necessity of abandoning the use of iron wires, and urged that they should on no account use such. A current cannot be sent through an iron wire without magnetising it all round circumferentially; and the next current, being a reverse one, has to demagnetise it and magnetise it again the opposite way. And as currents for telephonic working pass very rapidly, this perpetual magnetising and demagnetising is a drawback to the working. Not only should iron not be used, but even a good conductor, in the ordinary sense of the word, ought not to be used for telephonic working. A wire of higher resistance should be used than is customary for telegraphic working. The reason is this—that in telephone working, with variable and alternating currents, everything turns on the quantity called the "time-constant," or, rather, on the ratio between $2 \pi n$ L and R; if that quantity is large, retardation comes in. To prevent retardation we must make that ratio as small as possible; and, leaving iron out of the question, if we are working with a non-magnetic wire, the time-constant will depend simply on the geometrical form and length of the circuit, and on the specific resistance of the material. The time-constant can be made smaller by using silico-bronze or phosphor-bronze wire, which has a lower specific resistance than copper; and then, with wires of the same thickness or of the same weight per mile, we ought to get a more rapid rate of transmission. At the time I refer to I advocated the use of silico-bronze wire of a resistance based at somewhere about 40 ohms per mile—at any rate considerably higher than is used for telegraph work. It is not the resistance that prevents good working of telephones; it is the self-induction and leakage of the lines, and it is also the self-induction of the instruments

themselves to a very large extent. I may perhaps astonish some of my friends if I tell them that nearly all our telephone instruments are connected up wrong; *i.e.*, the coil of the receiving instrument, as a general rule, is in series with the secondary coil of the induction coil, whereas these coils should both be in parallel. In the present arrangement there exists an unnecessary amount of self-induction, and the result is that the lines are burdened with the very instruments put in to work them. I might go further on this point, and, in fact, I intended to say a good deal more about it, but perhaps I had better not go too far. In all induction coils, and particularly in the induction coil part of a telephone circuit, it is most desirable to get the greatest amount of mutual induction between the primary and secondary. Very well; we put our two coils together as closely as possible, one inside the other, and wind them of as many turns as are compatible with the conditions of working. But I am afraid that we too often forget the point that when we introduce a great many turns of wire into the secondary we not only add to the mutual induction of the two coils, but we add to the self-induction, *i.e.*, to that which retards the currents through the secondary. I should like to see an automatic arrangement introduced that would cut out the induction coil at the receiving end while receiving, and put it in again while transmitting. I am afraid it would be rather awkward. It is a much simpler matter to join the coil of the receiving instrument and the secondary wire of the induction coil in parallel with one another. Now, how are we to arrange the primary and secondary coils so as to get the maximum of mutual induction and minimum of self-induction? The coefficient of mutual induction between two coils cannot possibly be greater than the square root of the product of the coefficients of self-induction of the two coils; under exceptional circumstances it may be equal, but, on the other hand, it may be much less: for example, if the two coils are put a long way apart there will be no mutual induction, but plenty of self-induction in each of them. How are we to increase the mutual induction? That has been done for us in a very remarkable way by Mr. Langdon

Davies in the new kind of induction coils that he has introduced for telephonic working, in which the primary and the secondary are virtually laid side by side before they are wound up, by which means the mutual induction is at a maximum compared with the self-induction.

Finally, there is a point in connection with telephones that is also interesting as touching the lightning conductor problem. We have been taught by Professor Hughes how *not* to build lightning conductors; but there is one very curious point that I think is not generally known, if at all known, in this room, and I put it before Professor Hughes as a problem well worthy of his investigation. We know, and it has been abundantly proved, that an electro-magnet offers a very great spurious resistance to a rapidly changing current in the variable period. That fact is used, notably, in the Rysselberghe system for working telephones on telegraph lines, and also in my own telephone system. But the case I am going to put forward is one having no electro-magnetism at all about it, but something else in which there is precisely in the same kind of way an abnormal and very great spurious resistance to the current. Curiously enough, it is also one of the cases proposed for a lightning protector. It occurs in the following way:—Some time ago I was working a good deal with Hunning's transmitters, in which two layers of metal have granulated coke carbon between them; the current comes into one of the metal plates, and goes out at the other metal plate. It is a very good transmitting telephone. It is found that when working in a telephone line with a Hunning's transmitter, if a second Hunning's transmitter is inserted, it has an effect upon the first one very much like the effect of self-induction, yet there is no coil and no magnetism. It is a fact that a layer of charcoal or coke carbon interposed between two pieces of metal in a line does offer an appreciable amount of spurious resistance to a rapidly changing current; how, or why, I do not know, and cannot imagine, but it does. That is the very thing which, I believe, is known as "Varley's lightning protector." The lightning is supposed to go through it quite easily, but it offers a high apparent resistance to the telephone current.

Professor W. E. AYRTON, F.R.S.: Professor Silvanus Thompson has referred to certain work of my colleague and myself on self-induction, and therefore I take the liberty of rising to prevent a possible misconception being produced in the minds of those who have heard Professor Thompson speak. It is quite true, as he said, that we showed some time ago that when an intermittent current passed through a coil the effect of self-induction might be expressed as an increased resistance of the coil; but I think that that is not the increased resistance that Professor Hughes has brought to our notice, and I am inclined to think that perhaps the most important point in Professor Hughes's paper has been overlooked, I think I may say, by almost every speaker except Professor Forbes. The increased resistance which we showed an intermittent current to give to a coil was an increased resistance which, as Professor Thompson has shown, can be arrived at by the ordinary mathematical calculations. Now the question arises, Is the increased resistance that Professor Hughes has shown us to exist in a wire through which an intermittent current is flowing capable of being anticipated from the ordinary mathematical calculations? It could, of course, be obtained if one had a complete knowledge of nature; but can it be obtained from the ordinary mathematical calculations as they are given? I think the answer is, No.

We are so imbued with ordinary mathematics that somehow or other we try to explain all the results that Professor Hughes has obtained by the ordinary laws. I am not quite in agreement with Mr. Preece when he points out that mathematics, or theory, have always been behind experiments. In many cases that criticism is unfortunately quite true; but I think Sir William Thomson's theory regarding the retardation in submarine cables was elaborated, and the laws of the proper way in which cables should be made arrived at, before the conclusions were verified experimentally. In fact, the deductions drawn by Sir William Thomson regarding the propagation of electric waves in long submarine cables by employing the system of mathematical analysis that Fourier had used in investigating the flow of heat along a bar constituted one of the most brilliant examples of theory leading practice, and

made telegraphing through long submarine cables commercially possible. Without this mathematical work of Thomson's the results could only have been arrived at experimentally with the expenditure of a vast amount of money. Did time allow, it would be possible to mention many other cases where theory has been in advance of experiment.

Returning now to Professor Hughes's results, this question of increased resistance as distinct from self-induction is very, very important indeed. Mathematicians have usually assumed that in a simple circuit the growth of the current could be expressed completely if the law of variation of electro-motive force were known, as well as the resistance and coefficient of self-induction. My attention was, in any marked degree, first directed to the insufficiency of the ordinary mathematical analysis in this particular by a very curious experiment that was described to me some time ago by Captain Cardew. He told me that he had found out experimentally that if the mean square of an alternating current was measured by a Siemens dynamometer, the same result was not obtained as the mean square measured by the heat of an incandescent lamp; *i.e.*, if you altered the period of alternation of your dynamo machine so as to keep the luminosity of the lamp perfectly constant, then the mean square of the current as measured by the Siemens dynamometer appeared to be different. On discussing that with my colleague, Professor Perry, he said that it probably meant want of uniformity of distribution of the current-density in the wire of the dynamometer—a fact that was also referred to by Dr. Hopkinson, you may remember, at the last meeting, but I do not know whether he knew of the experiment of Captain Cardew to which I have referred. The important point to which Professor Hughes has drawn attention is, I think, that it has led us to see the important effect produced by this want of uniformity of the current-density, even in a straight conductor.

Professor Thompson has just said that he could not agree with the view stated by Professor Forbes that a current on starting went one way in the middle of the wire, and the other way in the outside; and I do not myself quite agree with that way of expressing this

want of uniformity in current-density. No doubt, if you had what Professor Forbes assumed—a current passing down the outside, and going up on the inside—you would have a waste of power, and consequently the effect of an increased resistance. But it is not necessary to assume a flow in opposite directions to explain the phenomenon; for if you have any want of uniformity of current-density in a conductor, my colleague and I have shown, in the following very simple way, that there must be an increase of resistance. For what do we mean by resistance in such a case? We mean increased heat generated per second per unit current; and it is quite easy to show that if you have a given current passing through a given wire, and if by any means you are able to destroy the uniformity of current-density, then, without any current passing in the opposite direction in any part, there must be an increase in the expenditure of power—that is, an extra production of heat per second per unit current, or an increased resistance.

Let C be the total current flowing through a wire, and let c be the current per unit area at any point of the wire, so that if da be the area of a small portion of the cross section,

$$\iint c \cdot da = C \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Let A be the area of the cross section, then $\frac{C}{A}$ is the mean current per unit area, and

$$\iint \frac{C}{A} \cdot da = C \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

If we consider any elementary filament of unit length of the wire, its resistance

$$\propto \frac{1}{da};$$

hence, since the current along the filament is $c \cdot da$, the heat generated per second in this filament

$$\propto (c \cdot da)^2 \times \frac{1}{da},$$

or

$$c^2 \cdot da.$$

Hence the total heat developed per second in the whole wire

$$= K \iint c^2 \cdot da,$$

where K is a constant.

On the other hand, if the current-density were uniform, and

equal to the mean current-density, the heat developed per second would be

$$= K\iint \frac{C^2}{A^2} \cdot da.$$

But the current-density not being uniform, let

$$c = \frac{C}{A} + x \quad \ldots \qquad \ldots \qquad \ldots \quad (3)$$

where x may have any positive or negative value; then

$$\iint c^2 \cdot da = \iint \frac{C^2}{A^2}\, da + 2\,\frac{C}{A}\iint x \cdot da + \iint x^2 \cdot da.$$

But $$\iint x \cdot da = 0,$$

since from (1), (2), and (3)

$$\iint c \cdot da = \iint \frac{C}{A}\, da,$$

and $\iint x^2 \cdot da$ is essentially positive. Hence

$$\iint c^2 \cdot da > \iint \frac{C^2}{A^2}\, da\,;$$

or the heat generated per second when the current-density is not uniform is greater than when the current-density is uniform for the same total current. That is to say, apart from what is usually understood by self-induction, there will be a seeming increase of resistance if the current-density is from any course not a uniform one. Now when a current starts or stops in a wire there must be *mutual induction* between the various streamlets of current in the wire; hence we may expect that on starting a current the current-density will be greatest near the surface of the wire and least near the centre, whereas on stopping the current it will be at the centre of the wire that the current-density will be a maximum. And since, as I have shown, any departure from a uniform current-density leads to an increase of resistance, it follows, as Professor Hughes has experimentally shown, that both on starting and on stopping a current there is an increase of resistance.

This, I think, is perhaps the most important of all the things that Professor Hughes has drawn our attention to. Some speakers at the last meeting, and others this evening, have endeavoured to explain his results somehow or other by the ordinary mathematical calculations, but I think we shall have to modify our calculations; in fact, Professor Hughes has led us to see that even in the single

straight conductor it is necessary, not merely to take into account the self-induction of the conductor, but also the well-known phenomenon of mutual induction, which has hitherto been usually confined to the induction of one current on another. In future, it seems possible that we shall have to introduce into our mathematical expressions, in order to express the true state of nature, a term dependent on the mutual induction of the various streamlets of the current, one on the other, which has the result of producing a want of uniformity of current-density, or, more simply, has the effect of producing a real increase of the resistance, altogether distinct from self-induction, of a wire traversed by an intermittent current.

The PRESIDENT: As the hour is already late, time will not permit now of my replying to the several speakers who have taken part in this discussion, or of communicating the results of some further researches which I had announced my intention of giving this evening. I will therefore communicate my remarks to the Secretary, that they may be printed with the paper and discussion in the Journal.

Mr. C. E. SPAGNOLETTI: Gentlemen,—I am very sorry that there was not time enough for further discussion upon this most interesting address; but if any gentleman has any further remarks to make, if he will kindly write them out and send them to the Secretary, their insertion in the Journal will be considered, so that the discussion may be completed.

The next meeting will take place on March 11th, 1886, when papers will be read on "Economy in Electrical Conductors" and on "Magnetic Resistance," by Professors Ayrton and Perry.

A ballot for new members then took place, at which the following candidates were elected:—

Foreign Member:

Ludwig Weiss.

Members:

R. C. Barker.	The Hon. Reginald Brougham.

Students:

Charles Garrard.	Charles Woodward Neele.

The meeting then adjourned.

THE PRESIDENT'S REPLY.

We have had a long and most interesting discussion, and I desire to express my warmest thanks to Lord Rayleigh, Mr. F. L. Pope, Prof. Forbes, Dr. Hopkinson, Mr. W. H. Preece, Dr. Fleming, Mr. Fitzgerald, Prof. Silvanus Thompson, and Prof. Ayrton, for their most kind appreciation of my researches. They have all recognised the enormous influence which self-induction exerts, and the necessity of studying the phenomenon in all its effects. There have been some points raised which are important, but to which I must reply as briefly as possible, as I am anxious to bring forward the results of some further researches, which of themselves will answer many of the questions asked.

Lord Rayleigh, while fully recognising the importance of the subject of my researches, seems not to have seized all the details of the method which I have employed, or the meaning of some of the terms which I have used. Professor Forbes has already replied to that portion of his remarks; but in his communication dated Feb. 24 Lord Rayleigh assumes that "the disturbance depends upon the rapidity of vibration, so that, in the case of ordinary mixed sounds, silence can be attained only approximately." Professor Silvanus Thompson has also asked me if the results depend on the rapidity of the contacts. In reply, I must state that in point of fact the rapidity of the contacts have no influence on the result, providing they are not more rapid than the rise and fall of the extra-currents.

Let us suppose that, instead of rapid contacts, we make and break the contact once only per minute, then, on making or breaking the contact, we shall hear a single blow or tap on the telephone; and if the communications of the bridge and telephone are arranged for the *stable* period, this sound will not be heard when the resistance of the bridge is perfectly adjusted. Suppose that we now change the communications so as to observe the *variable* period, still making and breaking contact but once per minute, we shall then find (if there is self-induction taking place in the wire under observation) that we have no longer silence at the previous adjustment of the bridge; if this disturbance is due only to the extra-currents, we can reduce it to zero by throwing

in from the sonometer an opposite momentary secondary current of *equal* value; but if the disturbance is due only to the resistance being changed, then we shall have to move the slide on the bridge until we have again perfect silence. In many cases we have to deal only with the extra-currents, in others there is a far greater change in the resistance of the wire than in the force of the extra-currents. Both can be adjusted separately or alone, but no change of the resistance slide will compensate for the induced currents, nor will any change of the sonometer affect in the slightest degree the required adjustment of the resistance slide; it is the first portion of the current that we are measuring by means of the telephone, or its action at the moment of making or breaking contact.

The object of my researches was to observe what takes place at the first instant of contact. To this the telephone responds with admirable precision, whereas, as I have already said, a galvanometer would be useless for such delicate experiments as I have made, where it is necessary that the self-induction of a few inches of straight wire may be readily perceived and accurately measured. The rate of speed of contacts, therefore, can be increased up to the point where the duration of the contacts is at least as long as the duration of the extra-currents. In short wires the duration in time of the extra-currents is exceedingly small, and much less than any duration of contact that I have used; a large electro-magnet would require a lengthened contact and a different method. The only advantage, therefore, of short contacts is the constant repetition of sounds or beats, enabling us the more readily and rapidly to find the required balance.

All of the important points mentioned in my paper have been verified by independent methods, and they have also been repeated with slow and rapid contacts, as well as with widely different external resistance in the battery circuit; but I wish to show that the induction bridge gives perfectly reliable results, and that its readings can never be changed or misunderstood.

I have chosen a fine German silver wire for the resistance bridge, because German silver has (even in the form of large wires) an extremely low inductive capacity; and this, when the

wire is fine, is again reduced to a mere fraction as compared with what it would be in wires of 1 millimètre diameter of different metals. To test the instrument, place a piece of similar-sized German silver wire in the arm A B, we do not then find any trace of self-induction, as all the four arms of the bridge are equal; we may vary its resistance by shortening the length of the wire, but the bridge can only then be adjusted to zero by moving the resistance slide. Under these conditions there is no difference perceived between the stable and the variable period, as the changes produced are equal on all sides. Let us now replace this German silver wire between A and B by a copper wire of the same resistance, we then find that the stable period gives exactly the same zero as previously, but that a disturbance takes place in the *variable* period, and that this cannot be adjusted by the *resistance* slide, but that it is completely reduced to zero by the opposed induction current of the sonometer. Again, if we heat this same wire, its resistance is changed, and can only be compensated by moving the resistance slide; if we make this wire into a loop or a parallel return, there is no change in the resistance, but the *self-induction is reduced* at once, as shown by the sonometer; winding this wire in a coil increases the induction, and, within certain limits, we may perceive no change in its resistance, whilst its *self-induction has increased* several hundred per cent. Now, suppose we increase the resistance by heating and the induction by coiling the wire, we have then two distinct effects of known values, and the measurements given by the resistance slide and by the sonometer are precisely those which would have been given by either when measuring them separately; and this again proves that where we have a case of change of resistance it can only be met by adjusting the resistance slide, and where we are measuring the electro-motive force of the extra-currents they can only be compensated for by the use of the sonometer.

The cause of the extra or momentary increased resistance of a wire during the variable period can be explained. The current, on entering the wire, produces an extra-current of an opposite name, and that this really opposes the passage of the current is proved by the upsetting of the previously balanced bridge; there

is, in fact, in this moment less resistance on the opposite side, and the balance can only be restored by the resistance slide.

There are, however, cases where this effect is entirely reversed, in which there is less resistance in the variable than in the stable period; this occurs when we are testing extremely fine wires with powerful currents, for the steady current heats the wire, thus introducing an extra resistance, which does not take place to the same degree with short contacts as in the variable period; but, as I have already said, care must of course be taken to avoid all such sources of error; and if we understand the subject, and know exactly where to look for errors, there should be no difficulty in constructing a bridge perfectly free from experimental error.

The instrument and method which I have employed have a great advantage over any previously used, as from the exquisite sensibility of the former we are enabled, not only to verify all the results obtained by previous observers from their experiments on coils, but to do that which no other instrument or method has previously enabled us to accomplish, viz., to observe the self-induction of straight wires and the laws of its reactions (as in the contiguous portion of the same current in straight wires and sheets) entirely separate and distinct from the mutual reactions of one part of a coil upon another. These I have shown to be quite different, as an iron coil has less self-induction than a copper one, whilst in straight wires the reverse is the case. We must not neglect this all-important point, for in no way do my researches contradict well-known results, they simply go further, and show the physical reasons for certain phenomena; and where theory has failed to predict, or previous experiments to show, this has been due simply to the fact that no instrument existed sensitive enough to record or measure the effects which take place in the self-induction of a comparatively short wire free from external reaction.

Self-induction in coils has been a subject which I had of necessity to study in relation to my printing telegraph instrument. The movement of my armature being extremely rapid, produced extra-currents of sufficient force to trouble other instruments on the same line. I finally vanquished this difficulty in

1860 by an arrangement whereby the armature, in rising, instantly short-circuits its own electro-magnet, and by mechanical means (peculiar to the instrument) is entirely separated from the line, placing the line at the same time direct to earth or battery, but leaving the electro-magnet open, so that the return of the armature produces no extra-currents that can affect the magnet or line. This has answered perfectly, and has been in use on all of my instruments since 1860 up to the present day. I have also used, since 1861, divided coils, whereby the current is passed through both coils in parallel, and not in series; this I use on lines less than 500 miles, not simply because of the diminished resistance, but because I found from experiments much less disturbing influence from the extra-currents. I have, however, lately, by the aid of the induction bridge, been not only enabled to measure this difference, but to trace it to its true cause, and the following table gives a representative result obtained from numerous coils of different sizes and resistances, and with or without iron cores:—

Coils formed of 3 mètres Silk-covered Copper Wire, 1 mm. in diameter, each Coil being 3 centimètres diameter.	Comparative Force of the Extra-Currents.
One coil alone	100
Two similar coils in series	174
Two similar coils in parallel, but separated 5 cm. from each other	55
Same two coils in parallel, but superposed	81
One single coil of thicker wire of exactly the same form, length, and resistance as the two coils in parallel	75

The table shows an increase of force when two coils are in series, but not quite double, as a portion is reduced by the increased or added resistance. This is a well known effect; but an interesting result is shown where the two coils are parallel and separated, giving then 32 per cent. less induction than the same coils superposed, and also 26 per cent. less than that of a single coil of precisely the same resistance. We can easily explain this, and trace the effect to the reactions of contiguous coils on each other.

I have shown a remarkable difference in the inductive

capacity of different metals when formed into wires of the same diameter; and as the order follows that of their respective specific resistances, it became an interesting study to know what would be the result if all the wires were of the same length and resistance. It is necessary to employ the same length, as the induction increases with the length; consequently a copper wire, compared with a brass wire of equal resistance, and therefore of greater length, would show a great difference in their inductive capacities. There are, however, several methods, free from experimental errors, which I have employed in this investigation.

If we take wires of different non-magnetic metals of the same length and diameter, and reduce them to the same resistance by an added resistance comparatively free from induction, such as carbon, I find that there is apparently no difference whatever in the inductive capacity of the different metals, all (yet tried) giving by this method very nearly the same result; but in this case we have added an external resistance, and thus prevented any difference of action due to the different density of the current in metals of high and low resistance.

If, instead of an added external resistance, we take wires of the same length and resistance, but of different diameters, we then find a marked difference in their inductive capacities; for instance, a pure copper wire, compared with a brass wire of double the diameter, shows a marked higher force in the copper wire. We might naturally believe that the brass wire, from its larger diameter, would give higher results than the smaller copper wire; but if we have thoroughly seized the importance of the phenomenon which I have demonstrated of the reaction of contiguous portions of the current on each other, we can easily prove that the larger the diameter of the wire the less will be its proportionate reactions, so that, whilst the resistance decreases directly as the increase in section, the reactions of the currents upon each other become *less* as the diameter increases, the resistance diminishing as a straight line, whilst the induction would follow a curve similar to that shown in the diagram.

The following table shows the electro-motive force of the extra-currents on wires and strips 1 mètre in length, a chemi-

cally pure copper wire of 1 mm. diameter being taken as the standard of 100, to which all the rest were compared:—

Wires of the same Diameter, but of different Resistance—1 mètre in length.	
Soft Swedish iron	500
Copper	100
Brass	65
Lead	50

Wires of the same Resistance, but of different Diameters—1 mètre in length.	
Soft Swedish iron	400
Copper	100
Brass	88
Lead	81

Strips of the same Width and Thickness, but of different Resistance—1 mètre in length.	
12 mm. wide, $\frac{1}{10}$ mm. thick.	
Copper	60
Brass	48
Iron	45
Lead	35

Strips of the same Resistance and Thickness, but of different Widths—1 mètre in length.		
$\frac{1}{10}$ mm. thick.		
12 mm. wide	Copper ...	60
42 " "	Brass... ...	45
72 " "	Iron	39
96 " "	Lead	29

In the above table, wires of the same diameter follow in the order of their resistance, iron alone being the exception; the same order is preserved in wires of the same resistance but of different diameters. In the latter case there is a nearer approach to equality, but they still show a difference of from 12 to 19 per cent., and whilst the non-magnetic metals have increased their inductive capacity with increased diameter, iron has fallen 20 per cent.; consequently, wires of different metals of the same resistance have not the same inductive capacity, owing, I believe, to the action of contiguous portions of the current, as I have already shown.

If we reduce the extra-currents by employing thin sheets or strips, there is in the case of iron a still more remarkable difference, for in strips of different metals of the same width, the force of the extra-currents in iron is actually less than that of brass, and if we compare an iron strip with an iron or copper wire of the same resistance, we have iron wire 500, copper wire 100, and the iron strip 45, or actually 55 per cent. less than the copper wire.

In the case of wires a nearer approach to equality in inductive

capacity is shown when they are of the same resistance, but in strips this is reversed, for here, when equality in resistance is produced by wider strips, the difference becomes greater, iron then having actually less inductive capacity than a lead wire of the same resistance.

This extraordinary result must be due, not only to the reactions of contiguous portions of the current being less in sheets or strips than in wires, but also from an imperfect formation of the circular magnetism which takes place in all iron wires on the passage of an electric current. This, however, is only a partial cause, as we can obtain a still further reduction of the extra-currents by employing numerous fine wires separated from each other, the circular magnetism in the latter case being perfectly formed in each wire; but we still have the maximum experimental reduction due to the separated portions of the current no longer acting on each other. Copper and all metals show a similar reduction when we separate the wires of a strand conveying a current, but when the numerous wires are brought close together, copper approaches in value that of a solid wire, whilst iron wires are but comparatively little influenced by their closer proximity.

I have tried all forms of conductors, such as square, stellar, tubular, &c.; they all show a gradual diminution of inductive capacity as compared with those of a solid circular section; in a solid conductor the maximum effect being obtained in the circular section, and the minimum in that of a wide flat sheet.

We can reduce the self-induction of any metal far below the comparative force that I have given, by widening the strip or, still better, by diminishing its thickness as we widen it, and it is evident that if we keep the same width and gradually increase its thickness, we then approach the conditions of a solid wire; consequently, where it is necessary that we should be able to utilise a given amount of copper in the best possible form, so as to convey a current of an enormously high tension but of short duration, as required in a lightning rod, we should widen the conductor as much as the mechanical stability and durability of the conductor will allow, and I believe that a lightning conductor of copper 1 mm. thick by 10 cm. wide would satisfy the

mechanical requirements whilst preserving the physical conditions necessary for a perfect conductor.

My experiments have shown clearly that a solid iron rod is unsuitable for a lightning conductor; but we may use a stranded iron wire or a flat iron sheet of the same conductivity as the copper. The iron wires should be galvanised, as all iron wires coated with a non-magnetic metal show a marked reduction in their inductive capacity; and here, as well as in the ribbon form of copper conductors, practice has guided our inventors in the right path, for it is an almost universal practice to galvanise iron wires in order to preserve them, and ribbon copper lightning conductors have been gradually replacing the most objectionable iron rod, for which there can be no defence based on experimental or scientific reasoning.

I have already given the results of a compound wire of copper and iron made by myself, but I have since (through the kindness of Mr. W. H. Preece) been furnished with some most admirable specimens of American compound wires, the copper being electro-deposited upon a core of steel wire, and also some specimens in which the core is of copper with a steel exterior. I have thus been enabled, not only to verify my previous results, but to prove that an exterior coating of copper has a most powerful influence in reducing the self-induction of its steel or iron core; for, if we take a given length of this wire and compare it with a similar length and diameter of copper wire, and taking for comparison the copper as a standard of 100, we have only 107, or 7 per cent. increase, for the compound wire, but if we file off the copper so as to leave the steel core bare, the inductive value of this same wire rises to 350.

In order to study this effect, let us place an iron wire in the interior of a closely fitting copper tube, insulated from it; this has no effect upon the iron wire, but if we join the exterior copper tube to the interior iron wire at both ends, the current passes through both at the same time, and the inductive capacity of this compound system is reduced almost to that of solid copper, as previously observed in the compound wires. These effects can be fully explained, when we reflect that the circular magnetism

produced by the passage of an electric current through an iron wire is produced only upon the exterior portion of the wire, and cannot take place when this exterior is, as in a compound wire, of copper; consequently a steel or an iron wire coated with copper of sufficient thickness is entirely free from this magnetic reaction.

Now, if an exterior coating of copper has such an effect in reducing the self-induction of its iron core, it follows that an opposite effect should be produced by coating a copper wire with iron. Experiments with this, and also with a copper wire inserted in a closely fitting iron gas tube, prove that the effect was as foreseen, viz., a remarkable increase in the inductive capacity of the wire.

One result, however, which I did not foresee, although it is clearly indicated in the experiments quoted in my paper, is that not only is the inductive capacity of the interior copper wire increased to a great degree, but that a copper wire coated with iron has a higher degree of self-induction than a solid iron wire; in fact, its inductive capacity is not only higher than is possible to obtain from the softest iron wire, but its *resistance in the variable period* is proportionately greater than any yet remarked in a solid iron wire. I have made numerous experiments on this subject, and they all show that whilst copper in a straight wire or a single *wide* loop has a far less inductive capacity than iron, it has, on the other hand, the property of being far more excited by the reaction of iron, so that a straight copper wire can be excited by this reaction to a degree greatly exceeding that of a straight iron wire under precisely the same conditions.

I will cite a few experiments which illustrate this point. A copper and an iron wire of equal resistance, and 1 mètre in length, were measured for their inductive capacity and resistance, the inductive capacity of the copper wire being as 100, as compared with 400 for the iron. The resistance of the copper in the variable period had only 8 per cent. increase, compared with 128 per cent. for the iron; but a great change took place when each of these was placed in the interior of an iron gas tube of sufficient diameter to allow of the wire being insulated. The force of the extra-currents in the copper wire then increased 350 per

cent., whilst the iron increased but 8 per cent.; the force of the extra-currents being now for copper 450, against 433 for the iron.

The influence of an exterior iron tube on the resistance of the wire during the *variable* period was still more marked. The copper wire, which without the exterior iron tube had only 8 per cent. increase, now showed 934 per cent. increase, or, by direct measurement, 1 mètre of this wire, during the rapid rise and fall of the current as in the variable period, had precisely the same resistance as 10·34 mètres in the stable period, or a much greater difference than I have obtained from an iron wire; for the iron wire insulated in the gas tube only showed an increase due to this tube of 22 per cent., giving a total of 178 per cent. difference, or, by direct measurement, 1 mètre of the iron wire with its insulated iron sheath, in the variable period, required 2·78 mètres to balance it in the stable period; thus copper shows more than three times the sensibility to an exterior sheath of iron than an iron wire itself. Iron appears to be self-contained, and, as regards self-induction, comparatively less acted on by an exterior influence. This is well shown in the case of coils, where the induction of a coil of insulated iron wire is but slightly increased by its own reactions, or those produced by the introduction of an iron core, as in an electro-magnet, whilst copper coils with an iron core show a remarkable increase. We can thus easily obtain extra-currents of ten times the electro-motive force of those from an iron coil of the same length, resistance, or diameter; and the resistance of a copper coil, which in the stable period may be far less than that of an iron coil, can, by means of its increased self-induction from the reaction of its iron core, be greater than that of an iron wire coil. At first glance this may be considered unfavourable for copper; but we must remember that whilst copper, in the presence of iron, can be excited to a far higher degree than iron, and consequently has stronger extra-currents and greater proportional increased resistance in the variable period, this is really a measure of the work it is capable of doing, for we are able by means of this property to obtain the high efficiency of transformation of energy as in the secondary currents. In point of fact, a dynamo machine having its electro-

magnet and armature wound with insulated iron wire would, irrespective of its resistance, have an extremely low efficiency as compared with those wound with copper; and as regards the resistance of either of these wires, there can be no doubt that the resistance of the armature of a dynamo, or, in fact, of any coil of wire as measured during the stable period, gives no approximate indication of what its *real* resistance is during the period in which it is doing work.

The following table shows the influence of an iron tube surrounding a straight iron or copper wire, compared with compound wires:—

Wires and Iron Tube each 1 mètre in length.	Comparative Electro-motive Force of the Extra-Currents.	Approximate Comparative Increased Resistance during the Variable Period (that of the Stable Period being taken as 1).
Copper wire, 2 mm. diameter, alone	100	1·08
Same wire insulated in the interior of the iron tube	450	10·34
Same joined to the tube at both ends	275	10·00
Same in contact with the tube throughout its length	200	7·83
Compound wire (copper interior with steel exterior)	325	4·35
Soft Swedish iron, 2 mm. diameter, alone ...	400	2·28
Same wire insulated in the interior of the iron tube	433	2·78
Same joined to the tube at both ends	240	2·70
Same in contact with the tube throughout its length	215	2·60
Compound wire (steel interior, copper exterior)	107	1·20

The table shows that the iron tube has a much greater effect upon the copper wire than on the iron wire, the effect in both cases being at its maximum when the tube is insulated from its central conducting wire, for when the wire is in contact with its tube there is evidently a shunt action, or species of eddy current, formed between the outer coating and the central portion. This I have been enabled to measure by interposing the telephone

between the inner core and the sheath, or, still better, by employing a double insulated sheath of iron or copper, and joining them together at one extremity, the opposite ends being joined through the telephone; by this means we are enabled to measure the differential effects of the secondary currents generated in an inner and in an outer sheath.

The table also shows the effect of joining the outer sheath at both extremities, thus allowing a true eddy current to form; this at once reduces the electro-motive force of the extra-currents, but has but little effect on the differential resistance in the variable period. If, however, we place the wire in contact throughout, so that the effect from the centre to the exterior of each portion can at once be partially neutralised, then there is a marked decrease in its resistance; and if, as in a compound wire, the exterior coating is in direct and still more intimate contact with the inner core, we then have the maximum reduction. We can thus prove that the shunt effect, or partial neutralisation of the extra-currents, takes place locally, and probably transversely. We see also, by its effect on the reduction of the resistance during the variable period, that the passage of an electrical current then takes place with less opposing resistance from the self-induction than could be the case if there were no internal partial neutralisation of the extra-currents. No doubt this effect also occurs in sheets and strips, and has its influence in causing the remarkable reduction of self-induction that I have already shown.

In conclusion, I once more desire to express my thanks to all who have taken part in the most interesting discussion that has followed the reading of my paper. Mr. W. H. Preece and Professor Forbes, who have seen my experiments, have borne testimony to the truth and care with which I have carried out these researches; and our well-known American electrician, Mr. Frank L. Pope, has cited examples showing that the superiority of a stranded iron wire was noticed even in the early days of telegraphy, and that the superiority of a compound wire over an ordinary iron wire is a well-known practical fact in the United States. He has also cited a case similar to the experiments of

Professor Guillemin and myself, where an electro-magnet was destroyed by lightning, notwithstanding that the telegraph line was joined direct to earth in advance of the electro-magnet. I am glad that many of the results of my researches are fully borne out by the practical experience of the past; and I hope that those which have as yet not been foreseen in theory or applied in practice will receive the same attention and verification that all discoveries should undergo, as I feel convinced that their truth will become more and more evident when repeated in the laboratory or applied in practice.

The Society of Telegraph-Engineers and Electricians.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR 1885.

RECEIPTS.

	£	s.	d.	£	s.	d.
£100 India [illegible] Stock, cost ...	[illegible]	[illegible]	[illegible]			
£100 Scinde, Punjaub, and Delhi Railway 5 % Guaranteed Stock, cost	121	17	6			
				998	2	6
Furniture—						
As per last Balance Sheet ...	154	15	0			
Less depreciation, say	15	10	0			
				139	5	0
Overdue Subscriptions estimated to realise				160	0	0
Stock in hand of Society's Journals and Ronalds Catalogue, estimated value				877	0	0
Books, Pictures, &c. (other than the Ronalds Library),						
As per last Balance Sheet ...	575	0	0			
Add value of Books, &c., since purchased and presented ...	65	0	0			
				640	0	0
Amount due for Advertisements in Society's Journal, 1885				25	5	0
Cash at Bankers, as shown above				590	9	6
				£3,643	2	3

EXPENDITURE.

	£	s.	d.
	£3,613	2	3

We certify that we have examined the Books, Vouchers, and Securities of the Society, and that the above Statement of Receipts and Expenditure and Estimate of Assets and Liabilities are correct, and exhibit the true financial state and condition of the Society.—*27th February*, 1886.

J. WAGSTAFF BLUNDELL
(WAGSTAFF BLUNDELL, BIGGS, & Co.,
Chartered Accountants),
FRED. CHAS. DANVERS,
Auditors.

THE LIBRARY.

ACCESSIONS TO THE LIBRARY TO MARCH 20, 1886.

By Alfred J. Frost, *Librarian.*

(*Works marked thus (*) have been purchased.*)

IT IS PARTICULARLY DESIRABLE THAT MEMBERS SHOULD FORWARD COPIES OF THEIR WORKS TO THE LIBRARY AS SOON AS POSSIBLE AFTER PUBLICATION.

Abel [Sir Frederick], C.B. Address delivered at the Opening of the 131st Session of the Society of Arts, Nov 19, 1884. 8vo. 25 pp. *London*, 1884

American Academy of Arts and Sciences. Proceedings. (New Series, Vol. XIII.; Whole Series, Vol. XXI.) Part I. From May to Oct., 1885. 8vo. 247 pp. *Boston*, 1885
[Exchange.]

Antwerp Exhibition. [*Vide* Mourlon, Ch.]

Anderson [Richard]. Lightning Conductors: Their History, Nature, and Mode of Application. 3rd Edition. 8vo. 470 pp. *London*, 1885

Bennett [Alfred R.] Description of a Telephonic Exchange and its Uses; being an Address delivered at the Town Hall at Inverness, 4th Sept., 1884. 8vo. 8 pp. *Glasgow*, 1884

——— Proposed Introduction of the Telephone Exchange System in Stirling, Alloa, and District. Report of a Public Meeting held at Stirling, Dec. 18, 1885. 8vo. 7 pp. *Stirling*, 1885

——— Proposed Introduction of the Telephone Exchange System in Dunfermline and District. Report of a Public Meeting held at Dunfermline on Feb. 3, 1886. Sm. 4to. 7 pp. *Dunfermline*, 1886

Berly [J. A.] Universal Electrical Directory and Advertiser. The Electrician's "Vade Mecum," containing a complete record of all the Industries directly or indirectly connected with Electricity and Magnetism, and the Names and Addresses of Manufacturers in Great Britain, America, the Continent, &c. 8vo. xi. + 388 pp. *London*, 1886

* **Bignami** [E.] **and others.** L'Elettricità e le sue Applicazioni. 8vo. 219 pp. [Callaboratori: E. Bignami, Prof. P. Pigorini, Prof. R. Ferrini, A. Casanova, Ing. Meardi, Ing. Ferraris, Dott. Barattieri, Dott. Schivardi, G. C. Garetti.] *Milano*, 1884

Cambridge Philosophical Society. Proceedings. Vol. V., Part IV. [Lent and Easter Terms, 1885.] 8vo. 94 pp. [pp. 221 to 314]. *Cambridge*, 1885
[Exchange.]

* **Delahaye** [Ph.] L'Année Électrique ou Exposé Annuel des Travaux Scientifiques des Inventions et des principales Applications de l'Électricité à l'Industrie et aux Arts. Deuxième Année. 8vo. 360 pp. *Paris*, 1886

Delany. [*Vide* Houston.]

Exposition à l'Exposition Universelle d'Anvers. [*Vide* Mourlon, Ch.]

* **Ferrini** [Rinaldo]. Illuminazione Elettrica. Cinque Conferenze tenute al circolo Alessandro Manzoni nell' inverno, 1882-83. 2a Edizione. 8vo. 68 pp. *Milano*, 1884

——— [*Vide* Jenkin, Fleeming.]

Franklin Institute. International Electrical Exhibition of the Franklin Institute, 1884. Report of the Examiners of Section XXII. (Section IVA., Classes 5, 6, and 7)—Electric Signalling Apparatus, Electric Registering Apparatus, &c., &c. 8vo. 96 pp. *Philadelphia*, 1886

——— International Electrical Exhibition of the Franklin Institute, 1884 Reports of the Examiners of Section XII. (Section I., Class 6)—Gas Engines. 8vo. 11 pp. *Philadelphia*, 1885

——— Report of a Special Committee on Competitive Tests of Dynamo-electric Machines, and on Mechanical and Electrical Tests of Conducting Wires. 8vo. 65 pp. *Philadelphia*, 1885

Giraud [J. B.] L'Organisation des Musées et le Fonctionnement de l'Enseignement du Dessin en Angleterre. 8vo. 111 pp. *Lyon*, 1885
[Presented by Col. Sir Francis Bolton, Vice-President and Hon. Sec.]

Houston [Prof. Edwin J.] Glimpses of the International Electrical Exhibition. 8vo. 8 pp. [Reprinted from the Journal of the Franklin Institute, Nov., 1884.] *Philadelphia*, 1884

——— Synchronism. 8vo. 11 pp. [Read before the American Institute of Civil Engineers, Oct., 1884.] *Philadelphia*, 1884

——— Notes on Phenomena in Incandescent Lamps. 8vo. 8 pp. [Read before the American Institute of Electrical Engineers, Oct., 1884.] *Philadelphia*, 1884

——— Synchronous-multiplex Telegraphy in Actual Practice. 8vo. 12 pp. [Reprinted from the Journal of the Franklin Institute, Sept., 1884.] *Philadelphia*, 1884

——— The Delany Synchronous-multiplex System of Telegraphy. 8vo. 19 pp. [Reprinted from the Journal of the Franklin Institute, Jan., 1884.] *Philadelphia*, 1884

——— Delany's System of Fac-simile Telegraphy. 8vo. 11 pp. [Reprinted from the Journal of the Franklin Institute, Dec., 1885.] *Philadelphia*, 1885

——— The Electrical Determination of the Velocity of Projectiles. 8vo. 13 pp. [Reprinted from the Journal of the Franklin Institute, Aug., 1885.] *Philadelphia*, 1885

* **Houston** [Prof. E. J.] **and others.** Primers of Electricity. 2nd Edition. 8vo. *London*, 1885

Indian Government Telegraphs. Telegraph Map of the Indian Government Telegraphs for 1885. Large Sheet. *Calcutta*, 1885

——— Administration Report of the Director-General of Telegraphs for 1884–85. Folio. 43 pp. *Calcutta*, 1885
[Presented by the Director-General of Telegraphs in India.]

Institution of Civil Engineers. The Theory and Practice of Hydro-Mechanics. 8vo. 208 pp. Plates. [A series of Lectures delivered at the Institution of Civil Engineers, Session 1884–85.] *London*, 1885

Iron and Steel Institute. Journal. No. 2. 1885. 383 + lxv. pp. *London*, 1885
[Exchange.]

Italian Telegraphs. Relazione Statistica sui Telegrafi del Regno d'Italia nell' Anno 1884. La. 4to. lvi. + 328 pp. *Roma*, 1885

Japanese Telegraphs. Tenth Report of the Director-General of the Imperial Government Telegraphs [T. Ishie] for the Fiscal Year ended June 30, 1884. 8vo. 26 pp. *Tokio*, 1884
[Presented by T. Ishie, Esq., Member.]

* **Jenkin** [Fleeming]. Elettricità. 8vo. 179 pp. Traduzione di Rinaldo Ferrini. *Milano*, 1885

Kew Observatory. Report of the Kew Committee for the Year ending Oct. 31, 1885; with Appendices containing results of Magnetical, Meteorological, and Solar Observations made at the Observatory. 8vo. 27 pp. [*Proc. Roy. Soc.*, 1885.] *London*, 1885
[Presented by G. M. Whipple, Esq.]

Lewis [Capt. J. F.], R.E. Appendix to Lectures on Permanent Fortification. [Appendix to Vol. VII. of "Occasional Papers of the Royal Engineers' Institute."] 8vo. 57 pp. *Chatham*, 1885

Lynd [William]. The Practical Telegraphist. 8vo. 264 pp. [2nd Edition.] *London*, 1885

McGregor [W.] Loss of Life and Property from Lightning at Home and Abroad. 8vo. 26 pp. *Bedford*, 1886

Mourlon [Charles]. L'Electricité à l'Exposition Universelle d'Anvers. 8vo. 303 pp. Plates. *Bruxelles*, 1885

Ordnance Department, U.S.A. Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year ended June 30, 1885. 8vo. 27 pp. *Washington*, 1885

Parliamentary Papers. Reports to the Trinity House of Deptford Strond on the Investigations made by a Committee of its Members into the Relative Merits of Electricity, Gas, and Oil as Lighthouse Illuminants. Fo. Part I., 70 pp.; Part II., 56 pp. Plates. *London*, 1885

* **Pietschmann** [W.] Der Photometer (Lichtmesser) erfunden und durch Naturliche Beweismittel Wissenchaftlich und Praktisch Begründet, &c. 8vo. 40 pp. *Leipzig*, 1885

Royal Institution. Proceedings. Vol. XI., Part II., No. 79. 8vo. 174 pp. [161 to 334 pp.]. *London*, 1886
[Exchange.]

Scott [Robert H.] The History of the Kew Observatory, Richmond, Surrey. 8vo. 50 pp. [*Proc. Roy. Soc.*, 1885.] *London*, 1885

Smith [Willoughby]. Magnetism. 8vo. 45 pp. *London*, 1885

Smithsonian Institution. Annual Report of the Board of Regents of the Smithsonian Institution, showing the Operations, Expenditures, and Condition of the Institution for the Year 1883. 8vo. 959 pp. *Washington*, 1885

* **Thompson** [Silvanus P.] Dynamo-electric Machinery. 2nd Edition. 8vo. 527 pp. *London*, 1886

Trinity House. [*Vide* Parliamentary Papers—Lighthouse Illuminants.]

* **United States Patent Office.** Index of Patents relating to Electricity. From July 1, 1883, to June 30, 1884. Appendix No. III. 4to. *Washington*, 1885

——— Alphabetical Lists of Patentees and Inventions for the Quarter ending June 30, 1885. La 8vo. 214 pp. *Washington*, 1885

* ——— Index of Patents relating to Electricity granted by the United States prior to July 1, 1881; with an Appendix embracing Patents granted from July 1, 1881, to June 30, 1882. 4to. *Washington*, 1882

* ——— Index of Patents relating to Electricity. From July 1, 1882, to July 1, 1883. Appendix No. II. 4to. *Washington*, 1883

ORIGINAL COMMUNICATION.

THE EXCHANGE TELEGRAPH COMPANY, LIMITED:
HEAD OFFICES—17 & 18, CORNHILL,
LONDON, E.C., *8th March*, 1886.

DEAR SIR,

The inconvenience caused by the acid vapour which is carried into the air when hydrogen gas is being evolved from acidulated water may be entirely obviated by placing any sort of loose cover immediately over the top of the vessels employed.

The minute globules of acid which are projected into the air upon the bursting of the bubbles at the surface of the liquid are always thrown vertically, in consequence of the uniform closing in of the liquid when the surface film of the bubble breaks. The film globulates and forms the projectile. If this be arrested before becoming absorbed by the atmosphere, nothing but the inodorous hydrogen is given off, thus making work in the vicinity of accumulators which are being charged much less unpleasant than it usually is, and preventing the corrosion of metal work in the vicinity.

A single thickness of the thinnest calico entirely intercepts the acid, and is as effective as the thickest fabric could be for this purpose.

Yours truly,

F. HIGGINS.

TO THE SECRETARY,
SOCIETY OF TELEGRAPH-ENGINEERS AND ELECTRICIANS.

ABSTRACTS.

E. MERCADIER—THEORY OF THE ELECTRO-MAGNETIC TELEPHONE RECEIVER.

(*Comptes Rendus*, *Vol.* 101, *No.* 20, *p.* 1001.)

From the results of a long series of experiments, the author was led to a theory of the telephone transmitter. This theory may be shortly explained as far as it relates to the receiver. The results of labours by many observers, extending over several years, may be summed up in two points. 1st. All the component parts of a telephonic receiver—core, bobbin, diaphragm, handle, &c.—all vibrate simultaneously. It is incontestable, however, that the most energetic effects are those of the diaphragm. 2nd. Diaphragms of any thickness up to 15 cm. may be used in the receivers. It resulted, therefore, from the first point that the diaphragm was no more indispensable in the receiver than it is in the transmitter; and from the second point, that there were in the receiver effects other than those which might result from the transversal vibrations corresponding to the fundamental sound and to the harmonics of the diaphragm.

To explain the action of the telephone receiver, it is sufficient to point out that the telephone transmitter with iron filings, previously described, is reversible, and can be used as a receiver. It results at once that in receivers, as in transmitters, the rigidity of the iron diaphragm is in no way indispensable for telephonic effects, such as the production of continuous series of successive sounds and of articulate speech.

The diaphragm only serves to increase the intensity of these effects, as in the transmitter, by concentrating the lines of force of the field, and by presenting a larger surface to the air. When the diaphragm is thick, the interior movements which take place in consequence of variations in the field, and which are transmitted to the surrounding air and to the ear, are solely movements of resonance. When it is thin, the particular movements resulting from its geometric form, and from its structure, can be added to the above; but then, as the harmonics of the voice in no way coincide with the proper sounds of the diaphragm, the intensity of the effect is increased at the expense of the good reproduction of the timbre. This is certainly one of the causes of the squeaky tone of most of the telephones with very thin diaphragms. But the thickness to be used has a maximum limit also, and hence the intensity cannot be increased beyond a certain point by increasing the thickness.

W. C. RECHNIEWSKI—THE TRANSFORMERS OF BLATHY, DERI, AND ZIPERNOWSKI.

(*La Lumière Electrique, Vol.* 18, *No.* 40, *Oct.* 3, 1885, *p.* 27.)

These transformers are constructed of various forms. In the first, the transformer consists of a Gramme ring of iron wires, the several convolutions of which are insulated from each other so as to prevent the formation of any Foucault currents; upon this ring are wound in sections the two circuits, primary and secondary, side by side. The windings are so arranged that the current always circulates round the ring in the same direction, in such a way that the lines of force in the ring form closed circuits and no magnetic poles are developed.

The second form, which is the more usual one, is, so to say, the reverse of the former, since the ring is formed by the copper wires of the primary and secondary circuits, while the iron wire is wound on outside. Other forms have been made in which the iron is inside in the shape of a solid and continuous bar, cylindrical or flat; always so arranged, however, as to provide a completely closed circuit for the lines of force.

As the resistances of the primary and secondary coils are relatively small as compared with the resistances of the corresponding circuits, the E.M.F. at the terminals may be taken approximately as proportional to the number of coils. If n_1 is the number of primary coils, and n_2 the number of secondary, and V_1 and V_2 the differences of potential, then

$$V_2 = \frac{n_2}{n_1} V_1;$$

and since $\frac{n_2}{n_1}$ is constant, the E M.F. at the terminals of the secondary circuit is proportional to that at the terminals of the primary.

The safest system of electric lighting being that where all the lamps are arranged in parallel, it is necessary to have a constant difference of potential between the leads from the secondary coils of the transformer; but we have seen that this can be accomplished by maintaining a constant difference of potential at the terminals of the primary coils. It is further necessary that any one or more of the transformers may be put in or out of circuit without affecting the working of the rest, and that the output of the dynamo is always proportional to the work being done, so that there may be no unnecessary waste. To effect this all the transformers are connected up in parallel on the primary circuit, and a regulator is introduced. When the resistance of the circuit diminishes by the shunting in of more transformers, the current increases, which would cause the E.M.F. at the terminals of the machine to decrease, a greater quantity of energy being absorbed by the interior resistances; this is counteracted by the regulator, which is, in fact, a transformer like the others, and which, when the E.M.F. decreases as mentioned, increases the exciting current of the electro-magnets of the alternate-current machine, and so brings back the E.M.F. to the fixed value.

J. MOSER—ELECTRIC AND THERMIC PROPERTIES OF SALINE SOLUTIONS.

(*Beiblätter, Vol.* 10, *No.* 1, 1886, *p.* 40. *Weiner Monatshefte für Chemie*, 6, *p.* 634.)

From Helmholtz's theories on the E.M.F. of cells with two different concentrated saline solutions and one metal, the vapour tensions of the solutions and the numbers representing the transport of the ions can be deduced. Following up some previous experiments, the author finds that the number representing the transport is equal to the E.M.F. in cases where transport of the ions occurs divided by the E.M.F. in cases where it does not occur; and he cites two cases as examples. A cell made up of zinc in chloride of zinc diluted with 100 parts of water on one side, and zinc in chloride of zinc diluted with 750 parts of water on the other side, has an E.M.F. of 0·0365 daniell; a battery composed of two chloride of mercury cells with these solutions has an E.M.F. of 0·0516 daniell. In the first case transport of the ions takes place, in the second it does not; the ratio of the two values is 0·71, while Hittorf found directly the value 0·70. Using two sulphate of zinc solutions, with 100 parts and 800 parts of water respectively, the author, under analogous circumstances, found the E.M.F. 0·0146 daniell and 0·0227 daniell; thus the quotient is 0·64, while Hittorf gives 0·636 and F. Kohlrausch 0·65. Thus we have a new method of determining the number representing the transport of the ions, and a new confirmation of Helmholtz's theory.

If a zinc plate immersed in chloride of zinc is opposed to a zinc plate immersed in sulphate of zinc, the degree of concentration of the solutions may be so adjusted that no current passes. If then a trace of water is added to the solution of sulphate of zinc, the zinc plate in it is attacked and dissolved, while zinc separates out from the chloride of zinc solution on to the other electrode; and conversely. The same thing happens with solutions of chloride and nitrate of zinc.

According to the author, the E.M.F. of the currents due to differences of concentration do not correspond to the heat effects produced by dilution. The electrical behaviour of nitrate of lead is the same as that of the zinc salts; the direction of the current due to concentration is the same. On the other hand, the solutions of zinc salts increase in temperature on dilution, while lead salts decrease.

SOHNCKE—THE SOURCE OF ORDINARY ATMOSPHERIC ELECTRICITY.

(*Beiblätter, Vol.* 10, *No.* 1, 1886, *p.* 58. *Sitzber. d. Jenaischen Ges. für Med. und Nat., Sept.*, 1885.)

The author replies to some objections raised against theories formerly put forward by him. He maintains Faraday's conclusion that ice becomes positively electrified by rubbing with water, other bodies negatively electrified. This is the only possible explanation of Faraday's experiment, which he has

repeated. The other conjecture—that the water blown against the ice brought the positive electricity with it—is contradicted by the fact that with pieces of ice melting away on the surface no production of electricity took place at all, although the film of water covering the ice ought to have taken up the positive electricity just as much as the ice.

The search for any other source of the atmospheric electricity leads to no practical result. If we suppose, as has been done, that the electrical charge of the lower air layers depends on the fact that all bodies experimented upon become negative when in contact with water, still the decided positive character of the ordinary atmospheric electricity in very fine weather, as well as the negative electricity of high-floating clouds, and generally of rain, remains unexplained, while the author's theory gives a ready explanation.

J. KLEMENCIC—EXPERIMENTAL RESEARCHES ON THE SPECIFIC INDUCTIVE CAPACITY OF SOME GASES AND VAPOURS.

(*Beiblätter, Vol.* 10, *No.* 2, 1886, *p.* 109. *Sitzungsber d. Wien Akad.*, 91, *p.* 712, *March* 19, 1885.)

The condenser used for the determination of the specific inductive capacities consisted of a pile of 30 nickel-plated brass discs, separated from each other by small ebonite washers 0·089 cm. thick. The pile of discs was surrounded by two cylinders of sheet zinc placed one within the other, the annular space between them being filled up with paraffin wax, and the top being closed by a zinc plate. The covering cylinders were connected to earth, and the whole was enclosed under the glass of an air pump, with which two reservoirs were connected, thus permitting of any gas being admitted into the glass receiver. Alternate discs of the condenser were connected together, fifteen being joined to a wire coming through the receiver, and fifteen being in connection with the plate of the air pump. In some experiments only 22 discs were used.

The influence of the pressure of the air or gas on the capacity of the condenser is negligible, as is the influence of changes of temperature, owing to the great mass of metal used in the apparatus—some 132 pounds in weight.

By means of a tuning fork interruptor, the condenser was alternately charged by being put in connection with a small battery of bichromate or Leclanché cells, and shunted into the circuit of a Meyerstein galvanometer of high resistance. The deflection of the galvanometer was compensated by leading the current of a small battery through a large resistance-box, and through the second coil of the galvanometer in a direction so as to oppose the action of the discharge from the condenser in the first coil; the resistance in the box was then altered until the galvanometer needle was brought to zero. Then in equal intervals of time equal quantities of electricity from both sources flow through the coils.

If a compensation has been obtained for a pressure (h) of the dielectric, and if the pressure is altered to H, the galvanometer shows a deflection (d), which,

however, does not correspond directly to the change of deflection (ϕ) caused by the condenser current alone, since a part flows through the compensating circuit, and not through the galvanometer.

If the specific inductive capacities in the two cases are D_h and D_H, then

$$D_B = \frac{D_H}{D_h} = 1 + \frac{q\,d}{\phi},$$

where q is a coefficient to be determined. If $H > h$, then d is positive; hence the specific inductive capacity increases with the density, and d increases proportionally to $H - h = B$. If, therefore, the deflection d has been observed for a difference of 760, we have

$$D_{760} = 1 + \frac{q\,d}{\phi} \times \frac{760}{B}.$$

Two large reservoirs were in connection with the air pump, and various gases were experimented upon, some 15-20 litres being used at a time. Temperatures were read off on a thermometer hung near the condenser. After each experiment the poles of the charging battery were reversed, so as to determine the absence of any conduction through the gas. The values of $\sqrt{D}$ found by the author are given in the following table, as well as, for the sake of comparison, the values as determined by Ayrton and Perry and by Boltzmann, and the refractive indices (n) :—

Gas.	$\sqrt{D}$. Ayrton and Perry.	$\sqrt{D}$. Boltzmann.	$\sqrt{D}$. Klemencic.	n.
Air	1·000750	1·000295	1·000293	1·0002927
Hydrogen	1·000650	1·000132	1·000132	1 0001387
Carbonic acid	1·001150	1·000473	1·000492	1·0004544
,, oxide	—	1·000345	1·000347	1·0003350
Nitrous ,, ...	—	1·000497	1·000579	1·0005159
Olefiant gas	—	1·000656	1·000729	1·000720
Marsh ,, ...	—	1·000472	1·000476	1·000442
Vapour of carbon bisulphide ...	—	—	1·001450	1·001478
,, sulphurous acid ...	1·00260	—	1·00477	1·0007036
,, ether...	—	—	1·00372	1·001537
,, ethyl chloride ...	—	—	1·00776	1·001174
,, ,, bromide ...	—	—	1·00773	1·001218

W. SIEMENS—ON THE DISCOVERY OF MR. FRITTS OF THE ELECTRO-MOTIVE ACTION OF ILLUMINATED SELENIUM.

(*Beiblätter, Vol.* 10, *No.* 2, 1886, *p.* 115. *Berl. Ber.*, 8, *p.* 147.)

The experiment of Fritts is confirmed, viz., that the conductivity of a film of selenium spread on a metallic plate, and made crystalline by heating, the

film being covered by a piece of thin gold leaf, is increased from 20 to 200 times by green light which passes through the gold leaf when rays of light are thrown perpendicularly upon it, as well as when the leaf is exposed to diffused daylight; much more, therefore, than in the case of Siemens' selenium grating.

A specimen not sensitive to light showed when the selenium was exposed to the light a continuous current during the time of the exposure; the direction of the current was in the direction of the propagation of the light, as was shown by the deflection of a galvanometer which was joined up on the one side to the piece of gold leaf and on the other side to the metal backing. The E.M.F. and current seem to be proportional to the intensity of the light as measured on a Bunsen photometer; for example, when the amount of light was respectively equal to 6·4—9·9—12·8—16·8 normal candle-power, the current was 18—30—40—48. The supposition of Fritts that the waves of light are converted directly into electrical motion is therefore confirmed. Dark heat rays produce no effect; any thermo-electric action is therefore excluded. When the plate is exposed directly to diffused daylight, the E.M.F. increases steadily from half-past nine in the morning until half-past eleven; it then remains constant for two hours, and then decreases up to three o'clock.

E. NACCARI and A. BARTELLI—PELTIER'S PHENOMENON IN LIQUIDS.

(*Beiblätter, Vol.* 10, *No.* 2, 1886, *p.* 118. *Atti della R. Acc. di Torino,* 20, *May* 31, *June* 21, 1885.)

Two glass cylinders, 16 cm. wide, were placed side by side in a vessel full of water, and a cardboard disc was fixed at the middle of each cylinder. At the bottom of each was a copper disc 13 cm. in diameter, to which was connected an insulated copper wire. In the lower half of each cylinder a solution of copper sulphate was poured up to the diaphragm, while above the diaphragm was a solution of zinc sulphate, in which was immersed a zinc disc, also 13 cm. in diameter, with a hole in the centre. The two zinc discs were joined up by a copper wire, and a current was passed through the apparatus from one copper disc to the other, the strength of which was measured by a mirror galvanometer, a deflection of one division of its scale corresponding to 0·000179 ampère. A very thin glass plate, with a hole in the centre, was fixed in each diaphragm. The bulb of a thermometer just entered this hole, the stem of the thermometer being enclosed in an india-rubber tube. The current from 1 or 2 Bunsen cells was sent through the apparatus for 15 minutes in opposite directions, and readings of the thermometer were taken each minute.

If i and i' are the observed currents, and q and q' the corresponding thermic effects, then the value of the Peltier phenomenon is given by the formula

$$h = \frac{(q\, i'^2 - q'\, i^2)}{(i\, i'^2 + i'\, i^2)}.$$

Experiments were made in which i and i' did not greatly differ, and the following values were found:—

$$i = 63—120—148—187.$$
$$10^6\,h = 71— 64— 72— 67.$$

The value of h is therefore nearly independent of i, and hence the Peltier effect is proportional to the current.

If the bulb of the thermometer was not at the point of contact of the two liquids, when these consisted of solutions of sodium sulphate of different degrees of concentration, or if the same liquid was used on both sides of the diaphragm, no particular value of h was obtained; so that the above results are not influenced by other heat actions than those due to the Peltier effect.

A table is given of the several results obtained with solutions of sulphates and chlorides of a great number of metals; but the results of the two classes of salts do not correspond.

If the whole apparatus was filled with water, and the thermometer surrounded by a semi-circle, half of iron wire and half of zinc wire, and the current passed through, then as a mean of the observations the value $h = 18$ was obtained; so that the values obtained for the Peltier effect between liquids are of the same order of magnitude as for metals. Since the Peltier E.M.F. between zinc and iron is 0·0024 volt, according to Bellati, the absolute value of the Peltier effect can be calculated in the case of the liquids experimented upon.

E. BIERINGER.—UNDERGROUND CABLES OF THE NUREMBURG TELEPHONE SYSTEM.

(*Elektrotechnische Zeitschrift, Vol.* 6, *Part* 11, 1885, *p.* 487.)

The chief exchange was established at the Central Post Office, which is situated outside the Old Town, in which are situated the chief business premises; and it was found impracticable to carry the trunk wires overhead from the Central Post Office into the Old Town. It was therefore decided that these trunk wires should be laid underground from the Central Post Office to two public buildings—the Custom House and the Armoury—whence the overhead wires could start. The cables were laid in iron troughs, the different lengths of which were connected by fish-plates, and covered with an iron lid. Ten cables were laid from the Post Office to the Custom House—a distance of 600 yards—where five ended; the remaining five being continued on to the Armoury, a further distance in the same direction of 620 yards.

The cables were each constructed in the following way:—The conductor was a copper wire 0·8 mm. in diameter; this was insulated with a double serving of prepared hemp, and then wrapped in tinfoil; 27 such wires and three bare copper wires were then laid up together into a strand, served with prepared canvas, and covered with two thicknesses of lead, each 0·9 mm. thick. In the troughs, where there was no wet, the above insulation was sufficient, but the ends of the cables were formed of short lengths of wire insulated with india-rubber.

The electrical data of the cables are the following, taken at 15° C.:—Conductor resistance, 56·25 ohms per mile; insulation resistance, 3,100 megohms per mile; capacity, 0·322 microfarad per mile.

R. CLAUSIUS—EXPLANATION OF THE DIFFERENCES BETWEEN FRÖLICH'S THEORY OF THE DYNAMO AND HIS OWN.

(*Elektrotechnische Zeitschrift, Vol.* 6, *Part* 12, 1885, *p.* 515.)

Dr. Frölich in a previous note had stated that the author had understood his demonstration as though he had entirely neglected the action of the current in the helix on the magnetic field of the dynamo, and had reminded him of the definition which he had given of the magnetic field. The author, however, denies this view of the matter. His objection against Frölich's theory is only concerned with the mathematical formula in which the magnetic field is expressed as a function of the current (I). In respect to this Frölich said in his note that in the formula of interpolation,

$$\frac{m\,\mathrm{I}}{1 + m\,\mathrm{I}},$$

used by him, the action of the helix on the magnetic field is contained in the constant of magnetisation (m).

This the author does not admit; but he maintains that it is impossible to express by so simple a formula, in which I appears only as a linear function, the quantities designated magnetism of the dynamo by Frölich, which include the whole force acting inductively on the rotating convolutions. This is alone the point of difference between the two.

The author has shown in a previous article that for a certain value of the constants employed by him in his own formulæ, Frölich's formula is only a special case of his own. Frölich contends, on the other hand, that this special case is just the one which occurs most frequently in actual practice. The author, however, maintains that under any circumstances in using Frölich's formula it is necessary to remember that it is only a simplified form of a general equation.

RESULTS OF THE MAGNETICAL AND METEOROLOGICAL OBSERVATIONS MADE AT THE ROYAL OBSERVATORY, GREENWICH, IN THE YEAR 1883, UNDER THE DIRECTION OF W. H. M. CHRISTIE, M.A., F.R.S., ASTRONOMER-ROYAL.

(*Communicated by* WILLIAM ELLIS, F.R.A.S., *Member, March* 26, 1886.)

This is the forty-third annual publication of magnetical and meteorological results as deduced from observations made at the Royal Observatory, commenced in the year 1841, and, until 1847, made at each two hours. Then Brooke's arrangement for continuous photographic registration was introduced, and has since been uninterruptedly employed. In the present volume we find in tables 1, 3, and 7, values of magnetic declination, horizontal force, and

vertical force, for each day; in tables 2, 5, and 9, mean hourly values through each month, indicating the monthly diurnal inequality of these elements. The values for declination are absolute; those for horizontal force and vertical force indicate variations of force only, in terms of ·00001 of the whole horizontal and vertical forces respectively (each as equal to unity). To obtain variations of these forces in C.G.S. units, the values in the several tables for horizontal force should be multiplied by 0·1810 (the mean value of horizontal force for the year), and those for vertical force by 0·1810 × tan. dip, or by 0·4375 (the mean value of vertical force for the year). Table 11 gives mean monthly results, table 12 mean diurnal inequalities for the year, and table 13 the range of declination and horizontal force on each day. Tables 15 and 16 give the constants which in each month represent the magnetic diurnal inequalities in the ordinary harmonic expressions, and tables 17 to 19 the results of the dip observations and the determinations of absolute horizontal force.

In a series of eighteen plates we have reduced copies of the photographic records for all days in the year on which much unusual magnetic motion occurred. The traces of declination, horizontal force, and vertical force are arranged one under another for facility of comparison, adding below them those of the earth currents registered in two separate circuits, each having earth connections of similar character—a copper plate. The sudden commencement of disturbance in all elements may be very well seen on April 2, July 29, September 15, October 16, and November 21. A marked case of considerable simultaneous movement occurs on October 5. The relation between unusual magnetic movement and earth currents is always close. The line joining the earth plates in one earth current circuit makes an angle with the magnetic meridian of 50°, counting from north to east, and that in the other circuit an angle of 46°, counting from north to west. Account of unusual disturbance of smaller amount is given in notes. The remaining tables refer to meteorology: among these are tables showing the mean electric potential of the atmosphere for each day, as well as mean hourly values in each month, indicating diurnal inequalities, the scale being arbitrary. In an introduction a full description of instruments and processes is given.

LIST OF UNABSTRACTED ARTICLES.

(*Comptes Rendus*, *Vol.* 101.)

No. 12.—**J. MARTIN**—New Arrangement of Condenser. **MORIN**—Improvements in the Alliance Magneto Machines.

No. 15.—**DELAURIER**—Source of Electricity in Batteries.

No. 16.—**G. DARY**—Electrical Causes of Earthquakes. **F. DE LALANDE**—New Current-measuring Apparatus. **E. MERCADIER**—Theory of the Electro-magnetic Telephone Transmitter. **A. RENARD**—Electrolysis of Salts.

No. 17.—**M. DEPREZ**—Transmission of Power from Creil to Paris.

No. 19.—**E. MERCADIER**—Two New Kinds of Radiophones. **C. CLAVERIE**—Magnetisation produced by Condenser Discharges.

No. 24.—**M. DEPREZ**—Construction of Dynamos intended for the Transmission of Power. **A. SARTIAUX**—Causes of the Breakdown of the Experiments between Creil and Paris.

No. 26.—**G. PLANTÉ**—Effects produced by the Rheostatic Machine. **MANCERON**—Application of the Principle of the Electric Transmission of Power.

(*Annales de Chimie et de Physique*, 1885.)

November.—**DAMIEN**—Experiments on the E.M.F. of Batteries with One Liquid formed by a Saline Solution.

December.—**A. CROVA**—Photometry of Lights of Different Colours.

(*Journal de Physique*, 1885-86.)

October.—**G. LIPPMANN**—An Arrangement by which the Potential due to a System of Solenoids may be arrived at without Calculation.

November.—**TERQUEM and DAMIEN**—Disruptive Discharges through Solids and Liquids.

January.—**DUHEM**—On Ampére's Law.

(*L'Electricien, Vol.* 9, 1885.)

No. 129.—**E. HOSPITALIER**—Electric Haulage on the New York Elevated Railways. **G. CABANELLAS**—Energy Transported in Great Quantity to a Great Distance. **P. JUPPONT**—The New Siemens Dynamos.

No. 130.—**E. REYNIER**—Electrodes for Accumulators. **A. BRILLOUIN**—Regularisation of Glow Lamps of Varying Intensity. **G. ROUX**—Use of Condensers in Telephony. **E. BOISTEL**—New Progress in the Theory of the Dynamo.

No. 131.—**E. REYNIER**—Electrodes for Accumulators. **E. BOISTEL**—New Progress in the Theory of the Dynamo. *Anon.*—The Tangent Galvanometer at Cornell University.

No. 132.—**P. JUPPONT**—Electric Lighting of the Eldorado Theatre. **F. DE LALANDE**—New Apparatus for Measuring Currents. **G. ROUX**—Kind of Current to be used for Charging Accumulators.

No. 133.—*Anon.*—Who Invented the Telephone?

No. 134.—**E. HOSPITALIER**—The Experiments at Creil. *Anon.*—Electricity used for Refining Sugar.

No. 135.—**P. JUPPONT**—The Cance Lamp. **E. BOISTEL**—New Progress in the Theory of the Dynamo.

No. 136.—**L. GREZEL**—Transmission of Power at Bellegarde.

No 137.—**E. HOSPITALIER**—High-speed Engines. *Anon.*—Electric Lighting of Mines.

No. 138.—**P. JUPPONT**—Report of the Trinity House on the South Foreland Experiments. *Anon.*—Cance's Liquid Rheostat.

No. 140.—**E. HOSPITALIER**—Dynamos with Periodic Currents.

No. 141.—**E. HOSPITALIER**—Historical Notes on the Transmission of Power.

(*La Lumière Electrique, Vol.* 18, 1885.)

No. 39.—**P. CLEMENCEAU**—The "Sun" Lamp in England. **G. DUCHÉ**—Electric Lighting in the Western States, U.S.A. **A. MINET**—Study of Galvanometers.

No. 40.—**M. DEPREZ**—Electric Transmission of Power. **G. RICHARD**—Sir W. Thomson's New Ammeters. **P. H. LEDEBOER**—Chemical Analysis by means of Electricity.

No. 41.—**B. ABDANK-ABAKANOWICZ** — Integrating Machines. **M. DEPREZ**—Electric Transmission of Power. **G. RICHARD**—Firing Mines by Electricity in China.

No. 42.—**J. MOUTIER**—The Wheatstone Bridge. **M. DEPREZ**—Electric Transmission of Power. **B. ABDANK-ABAKANOWICZ**—Integrating Machines. **W. H. PREECE**—Relative Advantage of Iron and Steel Wires for Telegraph Lines.

No. 43.—**G. SZARVADY**—The Direction of the Currents and the Position of the Brushes in Dynamos of the Paccinotti-Gramme Type. **M. DEPREZ**—Electric Transmission of Power. **B. ABDANK-ABAKANOWICZ**—Integrating Machines. **P. CLEMENCEAU**—The Electric Light at the Eldorado Theatre.

No. 44.—**M. DEPREZ**—Electric Transmission of Power between Creil and Paris. **G. RICHARD**—Electric Tramways and Railways. **M. DEPREZ**—Electric Transmission of Power. **C. DECHARME**—Analogies between Electric and Hydro-dynamic Phenomena. **A. MINET**—Study of Galvanometers.

No. 45.—**B. MARINOVITCH**—Electric Transmission of Power between Creil and Paris. **B. ABDANK-ABAKANOWICZ**—Integrating Machines. **P. MARCILLAC**—Udometer and Anemometrograph of Palmieri.

No. 46.—*Anon.*—Marcillac's Glass-plate Microphone.

No. 47.—**G. RICHARD**—Electric Regulators.

No. 48.—**P. H. LEDEBOER**—Bleaching by Electricity. **C. DECHARME**—Melsens' Pointed Lightning Conductors. **E. MERCADIER**—Theory of the Electro-magnetic Telephone Receiver

No. 49.—**P. CLEMENCEAU**—Seeing Objects at a Great Distance. **E. MERCADIER**—Theory of the Telephone. **C. DECHARME**—Analogies between Electric and Hydro-dynamic Phenomena. **E. DIEUDONNÉ**—Mode of Propagation of Electric Currents. **BERNSTEIN**—Quantity of Light produced by the Incandescence of Carbon Filaments.

No. 50.—**C. RECHNIEWSKI**—Study of Dynamos. **L. PALMIERI**—Production of Electricity by Combustion. **G. RICHARD**—Some Recent Telephones.

No. 51.—**E. DIEUDONNÉ**—Telegraphic Transmission on Underground Cables. **F. LARROQUE**—Plan for the Electrical Transmission of Images. **E. LACOINE**—New Electric Telemeter. **B. ABDANK-ABAKANOWICZ**—Integrating Machines. **A. CROVA**—Photometry of Lights of Different Colours. **E. GIMÉ**—Hissing of the Electric Arc.

No. 52.—**O. DE PEZZER**—Electric Light at the Paris Opera House. **A. MINET**—Calibration of Ammeters. **M. DEPREZ**—Construction of Dynamos for the Transmission of Power. **A. SARTIAUX**—Reasons for the Breakdown of the Creil Experiments.

(*Annalen der Physik und Chemie, Vol.* 26, 1885.)

No. 1.—**H. KAYSER**—New Form of Thermopile. **E. PFEIFFER**—Conductivity of Absolute Alcohol. **T. HOMEN**—Resistance of Rarefied Air. **V. v. LANG**—Measurement of the E.M.F. of the Electric Arc. **W. HANKEL**—Correction of an Hypothesis of v. Kolinko with respect to the Thermo-electric Distribution in Quartz.

No. 2.—**F. KOHLRAUSCH**—Conductivity of some Electrolytes in Extremely Dilute Solutions in Water. **A. OVERBECK**—A Phenomenon in Electric Vibrations of the Nature of Resonance. **E. DORN**—The Law of the Equal Production of Both Kinds of Electricity so far as it relates to Pyro-Electricity. **E. WIECHERT**—Conductivity of Serpentine.

No. 3.—**F. KOHLRAUSCH**—Inconstancy of the Damping Coefficient of Galvanometers, and its Influence on the Determination of Absolute Resistance.

No. 4.—**E. EDLUND**—The Resistance of the Electric Arc. **F. HIMSTEDT**—Determination of the Ohm in Absolute Measure.

(*Beiblätter, Vol.* 9, 1885.)

No. 11.—**G. P. DAHLANDER**—A Property of Electric Potential. **A. BATTELLI**—Deductions from Kohlrausch's Theory of Thermo-electric Phenomena. **ZOMAKION**—Laws of the Passage of Electricity through Gases. **C. FIEVEZ**—Influence of Magnetism on the Character of the Lines in the Spectrum.

No. 12.—**A. ROITI**—The Electric Calorimeter compared with Riess's Thermometer. **A. RIGHI**—New Researches on the Hall Phenomenon. **A. RIGHI**—Photography of the Electric Spark. **E. VILLARI**—Researches on the Inner and Outer Discharge of Condensers.

(*Vol.* 10, 1886.)

No. 1.—**L. PALAZZO**—Error in the Deflection Method due to the Displacement of the Suspension Fibre from the Vertical. **A. ECCHER**—Electric Discharges. **A. PIZZARELLI**—Decomposition of Non-saturated Vapours of Organic Bodies by a Succession of Sparks.

No. 2.—**H. A. LORENTZ**—Application of the Second Law of Thermo-Dynamics to Thermo-electric Phenomena.

(*Centralblatt für Elektrotechnik, Vol.* 7, 1885.)

No. 25.—**J. KESSLER**—Measurements of Currents by the Tangent Galvanometer. **A. v. OBERMEYER**—Alterations in Mirror Galvanometers for Absolute Measurements.

No. 26.—*Anon.*—Riedinger's Insulators and Cut-outs. *Anon.*—Edison's Work in Telephony.

No. 27.—*Anon.*—Standardising of Resistances in France. *Anon.*—Note on Electro-Magnetism. *Anon.*—Edison's Work in Telephony.

No. 28.—*Anon.*—Bazin's New Cell.

No. 29.—*Anon.*—The Underground Conductors at the Philadelphia Electrical Exhibition.

No. 30.—*Anon.*—Trouvé's Electric Lighting Apparatus. *Anon.*—New Apparatus for the Determination of Specific Gravity.

No. 31.—**Dr. KRIEG**—Relation of Polarisation to the Nature of the Electrolyte.

No. 32.—**Dr. KRÜSS**—The Measure and Distribution of Light. *Anon.*—The Underground Conductors at the Philadelphia Electrical Exhibition.

No. 33.—*Anon.*—Phelp's Method of Telegraphing to Trains in Motion. *Anon.*—Lalande's Current Measurer. *Anon.*—Practical Measurements with the Tangent Galvanometer.

No. 34.—**J. KRÄMER**—Determination of the Horizontal Component of the Earth's Magnetism. **Dr. KRÜSS**—Compensation Photometer.

No. 35.—**Dr. A. v. WALTENHOFEN**—Deprez's Characteristic, and the Influence of the Armature Current on the Intensity of the Magnetic Field.

No. 36.—**H. BECQUEREL**—Measurement of the Magnetic Rotatory Power of Bodies in Absolute Units.

(*Elektrotechnische Zeitschrift*, 1885.)

No. 11.—**W. H. PREECE**—On the Comparative Value of Iron and Copper Wires for Telegraph Lines. **E. VON TAUND-SZYLLS**—Differential Selenium Recorder and Relay. **RÜHLMANN**—The Arc Lamp of the Chemnitz Telegraph Works. *Anon.*—New Pocket Battery. *Anon.*—Use of the Telephone on Railways.

No. 12.—**TRIEBEL**—Use of the Telephone for Railway Service. **A. WEINHOLD**—Portable Mirror Galvanometer, with Scale, in the Eye-piece of the Telescope. **A. WEINHOLD**—Equations for Series and Shunt Dynamos. *Anon.*—Berliner's Telephone System with Triple-contact Microphone.

(1886.)

No. 1.—**J. ZACHARIAS** — Electrically-worked Tramways. **Dr. G. STEIN**—Experiments with a Dynamo Machine. **HUMMEL**—Unipolar Dynamos. **R. v. FISCHER-TREUENFELD**—Spanish Military Telegraphs. **E. ZETSCHE**—Denison's Copying Telegraph. *Anon.*—Naglo's New Telephone System. **Dr. A. TOBLER**—Winter's New Block Apparatus. **A. WEINHOLD**—Lightning-Rod Testing Apparatus.

No. 2.—**A. WEINHOLD**—Equations for Series and Shunt Dynamos. **v. GAISBERG**—Experiments on Dynamos. **R. v. FISCHER-TREUEN-FELD**—Spanish Military Telegraphs. *Anon.*—Telegraphic Communication with Trains in Motion.

JOURNAL

OF THE

SOCIETY OF

Telegraph-Engineers and Electricians.

Founded 1871. *Incorporated* 1883.

VOL. XV. 1886. No. 61.

The One Hundred and Fifty-third Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, 11th March, 1886—Professor D. E. HUGHES, F.R.S., President, in the Chair.

The minutes of the previous meeting were read and approved.

The names of new candidates were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council, viz.:—

From the class of Associates to that of Members—

Robert Portelli. | P. W. Willans.

The PRESIDENT: The Balance Sheet for the past year having been distributed among the members of the Society, in order that those who desire information upon any of the items it contains may put questions thereupon, I presume that it may be taken as having been read. It is somewhat unfortunate that our Honorary Treasurer is absent to-night, being out of town on official duties; but the Secretary, Mr. F. H. Webb, is prepared to answer interpellations. I beg to move that the Balance Sheet be received and adopted.

Mr. Shelford Bidwell: I beg to second the motion.

No question being asked, the President put the motion, which was carried *nem. con.*

The following paper was then read:—

ECONOMY IN ELECTRICAL CONDUCTORS.

By Professors W. E. Ayrton, F.R.S., and John Perry, F.R.S., Members.

I. At the meeting of the British Association in 1881, a most valuable solution of a very important problem was given by Sir William Thomson regarding the proper sectional area to give to a copper conductor used in transmitting electric energy. In the account of his communication given in the "Report of the British Association" for that year, it is stated that "he remarked that (contrary to a very prevalent impression and belief) the gauge to be chosen for the conductor does not depend on the length of it through which the energy is to be transmitted. It depends solely on the strength of the current to be used, supposing the cost of the metal and of a unit of energy to be determined." And he concluded that for twelve hours per day work "the sectional area of the wire in centimètres ought to be about a fiftieth of the strength of the current in webers," if a horse-power be taken as worth £10 per year, copper as £70 per ton, and 5 per cent. be allowed for interest.

It is, of course, well known that this rule has to be departed from when considerations have to be taken into account other than that of obtaining maximum economy: for example, the necessity in any general system of electric lighting of maintaining the potential difference along the mains constant within certain limits, may lead us to adopt a thicker conductor than is given by the rule of one square centimètre per fifty amperes; while, on the other hand, our desire to obtain a large magnetic effect in an electro-magnet, or a large electro-motive force in a dynamo, induces us to employ a much thinner conductor than the rule indicates. But, at any rate, when the cost of copper and the cost of coal are the leading considerations, it might appear that

Thomson's rule ought to be rigidly adhered to, proper allowance being, of course, made in any particular case for the number of hours of working, the cost per ton of copper, the annual rate of interest and depreciation, and the annual cost of an electric horse-power. Indeed, this is the view that we, and possibly other electrical engineers, have taken, and it was not until comparatively recently, when in actual calculations regarding the proper dimensions to give to the conductors in telpher lines, that we recognised that Thomson's solution of the most economical section to give to a conductor was quite inapplicable in a variety of cases connected with electric transmission of power.

II. Let us consider a little more in detail the solution that Thomson gave. He arrived at an expression for the total waste per mile in a conductor arising from the generation of heat and interest on copper which we find convenient to put in the following form:—

$$C^2 r + \frac{t^2}{r} \quad \dots \quad \dots \quad \dots \quad (1)$$

where C is the current in amperes, r the resistance of the conductor per mile in ohms, and t a constant which depends on the annual interest on the value of a ton of copper (allowing for depreciation) and the annual cost of an electric horse-power for the number of hours per year that power is required. Our expression (1) is, in fact, the *total* rate of waste per mile, *reckoned in watts.**

In order that this may be a minimum for a given value of C,

$$C = \frac{t}{r} \quad \dots \quad \dots \quad \dots \quad (2)$$

If we take £15 as the annual interest (allowing for depreciation) per ton of copper (that is to say, about 12 per cent. on £125—a fair price per ton for good conductivity copper, including the value of the necessary amount of insulation), and if we take £15

* Although it would not avail bankers to reckon that a business which cleared £1,500 a year produced so many watts, yet such a mode of reckoning is very convenient in problems like the one under consideration. With an electric horse-power costing £15 per annum the business clearing £1,500 annually might be regarded as producing 74,600 watts, and 5 per cent. per annum interest on £120 might be regarded as an income of 298·4 watts.

also as the annual cost of an *electric* horse-power for the number of hours per year that power is required, it is easy to show that

$$t^2 = 297{\cdot}3;$$

so that (2) reduces itself to

$$C = \frac{17{\cdot}24}{r}$$

$$= \frac{17}{r} \text{ approximately} \quad \ldots \quad (3)$$

corresponding with about 60 amperes per square centimètre, or 393 amperes per square inch.

Now suppose that we desire to apply this result to such a case as the following, which will frequently be met with in electric lighting and transmission of power:—What size of copper conductor ought to be employed when a certain amount of power, P watts, has to be furnished at the end of a conductor n miles long, and when the highest potential difference we are allowed to use from considerations of safety, or, it may be, that is allowed us by the Board of Trade, is V volts?

Let C be the current in amperes, then, since the maximum potential difference must be at the near, or dynamo, end of the line, the potential difference at the farther end will be

$$V - C\,n\,r,$$

if r is the resistance per mile of the conductor in ohms, and if the earth be used as the return; or if r is the resistance per mile of the going and return conductor,

$$\therefore P = C\,(V - C\,n\,r) \quad \ldots \quad \ldots \quad (4)$$

and, by Thomson's rule,

$$C = \frac{t}{r};$$

hence we have two equations from which to determine C and r. The values of C and r so obtained are—

$$C = \frac{P}{V - n\,t} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

and

$$r = \frac{t\,(V - n\,t)}{P} \quad \ldots \quad \ldots \quad (6)$$

and these are the values of C and r which, it might appear, ought to be selected in order to obtain maximum economy.

As an example, let

$$P = 10{,}000 \text{ watts},$$
$$V = 200 \text{ volts},$$
$$n = 10 \text{ miles},$$
$$t = 17;$$

then, from (5) and (6),

$$C = 333 \text{ amperes},$$

and

$$r = 0{\cdot}051 \text{ ohm}.$$

But it is easy to see from (4) that with an initial potential difference of 200 volts the same power, 10,000 watts, can be delivered at the end of 10 miles of a conductor having the same resistance per mile if, instead of using 333 amperes, we use only 59 amperes; and as the loss of power in heating is proportional to the square of the current, the waste in heating when using the smaller current will be only about the thirty-second part of what it would be if we used the current given us by equation (5).

In fact, for each value of r there are two solutions of C which satisfy (4), whereas only one of them can satisfy Thomson's equation of economy (2). In this example, then, *thirty-two times as much economy in coal will be obtained by neglecting Thomson's rule as by following it.*

III. Now what is the explanation of this? The cause cannot, of course, be due to any error in Thomson's reasoning, and it arises from the fact that Thomson's solution gives the minimum value of the expression

$$C^2 r + \frac{t^2}{r}$$

only when C is regarded as a constant, and r as the *sole* variable. But if, as in the present case, both C and r in this expression are variables connected by some equation such as

$$f(C, r) = 0,$$

then the equation connecting C and r which makes the total waste a minimum is *not*

$$C = \frac{t}{r}.$$

In fact, when the maximum difference of potentials V is fixed, the current C can only be regarded as a constant when the power *put into the line at the dynamo end,* $V\,C$, is given, and when the

amount delivered at the other end is, so to say, left to chance. Under these conditions Sir William Thomson has given us a most useful rule for determining the size to give to the conductor to obtain maximum economy, but his solution can only be used when the value of the current is previously known.*

But since in many practical cases it is the amount of power that has to be furnished at the distant end of the line that is fixed for us by the contract, C must not be regarded as a constant, and a totally different method must be employed to obtain the size of conductor to be employed so that the waste of power in heating the conductor, together with the interest on the value of the copper, may be a minimum. For not merely, as we have shown, does the current of 333 amperes and a resistance of 0·051 ohms per mile, as determined from (5) and (6), lead to thirty-two times as much waste in heating as will be produced by using the equally effective current of 59 amperes with the same conductor, but, as we shall show, there is a solution of the problem even more economical than this.

IV. If we write $F(C, r)$ for the total rate of waste per mile, which is

$$C^2 r + \frac{t^2}{r},$$

and if our supply condition connecting C and r is

$$f(C, r) = 0,$$

then the equation which gives us the minimum is

$$\frac{dF}{dC} \times \frac{df}{dr} - \frac{dF}{dr} \times \frac{df}{dc} = 0.$$

Hence, performing the partial differentiations on our two functions (1) and (4), we have

$$2\,C r \times C^2 n - \left(C^2 - \frac{t^2}{r^2}\right)(2\,C n r - V) = 0 \quad \dots \quad (7)$$

Eliminating r from (4) and (7), we obtain

$$C^2 - 2\,C\frac{P}{V} + \frac{P^2}{V^2 + n^2 t^2} = 0 \quad \dots \quad (8)$$

$$\therefore C = \frac{P}{V}\left(1 \pm n\,t\sqrt{\frac{1}{V^2 + n^2 t^2}}\right),$$

* For the solution when V and r are given, and C is the variable, see the remarks made by the authors in the discussion.

and, as $C\,V$, which is the power put in at the dynamo end of the line, must necessarily be greater than P, the power given out at the distant end, it follows that the plus sign is alone admissible. Hence the current which must be used to obtain maximum ceonomy is

$$\frac{P}{V}\left(1 + n\,t\sqrt{\frac{1}{V^2 + n^2\,t^2}}\right) \quad \dots \quad \dots \quad (9)$$

Substituting the values employed in the previous example for P, V, n, and t, we find that the current which gives maximum economy is

82 amperes;

and, from (4),

$$r = \frac{C\,V - P}{C^2\,n} \quad \dots \quad \dots \quad (10)$$

so that the resistance per mile that gives maximum economy is

0·0954 ohm, and *not* 0·051 ohm.

We may now use the three sets of values of C and r that we have obtained in connection with our example, and find what values they give to the expression

$$C^2\,r + \frac{t^2}{r},$$

which represents the total rate of waste per mile, reckoned in watts, due to the production of heat in the conductor, and to the interest, including depreciation, on the value of the conductor.

A. Using the values of C and r given by (5) and (6), obtained from combining Thomson's condition of maximum economy with the condition of electrical supply, we have for the above expression

$$333^2 \times 0{\cdot}051 + \frac{289}{0{\cdot}051} = 5{,}654 + 5{,}666$$
$$= 11{,}320 \text{ watts per mile.}$$

B. Using the value of r given by (6), and the second value of C given by (4), we have for the above expression

$$59^2 \times 0{\cdot}051 + \frac{289}{0{\cdot}051} = 177 + 5{,}666$$
$$= 5{,}843 \text{ watts per mile.}$$

C. Using the values of C and r given by (9) and (10), the

proper equations to be used for obtaining maximum economy, we have for the total waste

$$82^2 \times 0{\cdot}0954 + \frac{289}{0{\cdot}0954} = 641 + 3{,}030$$
$$= 3{,}671 \text{ watts per mile.}$$

Although, then, the current of 82 amperes and the resistance of 0·0954 ohms per mile lead to a greater waste in heating than the current of 59 amperes and the resistance of 0·051 ohms per mile, yet the former are the most economical to employ. In fact, it will be found that a conductor having a resistance per mile either greater or less than 0·0954 ohms leads, in our example, to greater waste than is produced by employing this conductor.

V. For the purpose of constructing a table to be used for determining the proper current and resistance of conductor per mile to be selected in various cases in order to obtain maximum economy, and for determining the waste that will occur per mile in heating, and the amount of interest on the value of the copper per mile, when this current and resistance per mile are employed, let

$$\frac{n\,t}{V} = tan.\ \phi;$$

then $$C = \frac{P}{V}(1 + sin.\ \phi) \quad \ldots \quad \ldots \quad (11)$$

and $$r = \frac{V^2}{n\,P} \cdot \frac{sin.\ \phi}{(1 + sin.\ \phi)^2} \quad \ldots \quad \ldots \quad (12)$$

Using these values, the following table (No. I.) has been calculated for V equal to 200 volts, and P equal to 20,000 watts, in order to illustrate the way in which the current, sectional area of the conductor, and current-density proper to be used to obtain maximum economy, vary with the length of the line. The first column gives n, the number of miles at the end of which this power is to be furnished if the earth be used as the return. If the earth be not used as the return, then n will be *twice* the distance between the two ends of the line. The second column is $\frac{n\,t}{V}$, where t is taken as 17. The third and fourth columns give ϕ, and $sin.\ \phi$; the fifth and sixth the current (C) in amperes that should be employed, and the resistance (r) in legal ohms per

mile that should be given to the conductor to obtain maximum economy; column 7 gives the sectional area (A) of the conductor in square inches, the resistance of one mile of copper wire of 98 per cent. conductivity at 20° C., one square inch in section, being taken as 0·04378 legal ohms. Column 8 gives D, the current-density—that is, the number of amperes per square inch; columns 9 and 10 P_1, the power, in watts, wasted in heat per mile, and P_2, the watts wasted per mile as interest, including depreciation, on the value of the conductor. The last column contains the values of P_3, the total rate of waste, in watts, per mile.

Table I.

To furnish 20,000 watts at the end of n miles.

1	2	3	4	5	6	7	8	9	10	11
n.	$\frac{17}{200} n$.	ϕ.	$\sin. \phi$.	C.	r.	A.	D.	P_1.	P_2.	P_3.
·1	·0085	0° 29′	·0084	100·8	·1652	·2651	380·2	1679	1749	3428
·5	·0425	2° 26′	·0425	104·3	·1564	·2800	372·5	1699	1847	3546
1	·085	4° 52′	·0848	108·5	·1441	·3038	357·2	1695	2005	3700
2	·17	9° 39′	·1677	116·8	·1229	·3563	327·8	1675	2351	4026
4	·34	18° 47′	·322	132·2	·0921	·4753	278·1	1609	3137	4746
6	·51	27° 2′	·4545	145·5	·0716	·6115	238·0	1514	4036	5550
8	·68	34° 13′	·5623	156·2	·0575	·7614	205·1	1403	5026	6429
10	·85	40° 22′	·6477	164·8	·0477	·9179	179·5	1295	6058	7353
15	1·275	51° 54′	·7869	178·7	·0328	1·335	133·9	1047	8810	9857
20	1·7	59° 32′	·8619	186·2	·0241	1·817	102·5	835	11911	12746
30	2·55	68° 35′	·931	193·1	·0166	2·637	73·2	618	17530	18148
50	4·25	76° 46′	·9735	197·4	·0099	4·423	44·6	385	29191	29576
70	5·95	80° 27′	·9861	198·6	·0071	6·166	32·2	280	40704	40984
100	8·5	83° 18′	·9932	199·3	·0049	8·935	22·3	194	58979	59173

The latter portion of this table has been calculated for the purpose of illustrating how the current, sectional area of the conductor, and current-density necessary to be used to obtain maximum economy, vary with the length of the line, and not because anyone would think of attempting to transmit thirty horse-power fifty or a hundred miles with a potential difference of only 200 volts at the dynamo.

The problem considered by Sir William Thomson led to the

result that in order to obtain maximum economy the area of the conductor depended solely on the current, and was independent of the length of the line, or, in other words, the current-density was a constant. But from the preceding table we see that *if a given amount of electric power has to be furnished at the end of a line, with a given potential difference at the dynamo, maximum economy is obtained, not by keeping the current-density constant, but by making it diminish as the length of the line becomes greater.*

In order to employ this table for other amounts of power to be furnished at the distant end of the line, it is to be observed that since

$$C = \frac{P}{V}(1 + sin.\,\phi) \qquad \ldots \qquad \ldots \qquad (13)$$

$$r = \frac{V^2}{n\,P} \cdot \frac{sin.\,\phi}{(1 + sin.\,\phi)^2} \qquad \ldots \qquad \ldots \qquad (14)$$

and since the sectional area of the conductor,

$$A = \frac{0{\cdot}04378\,n\,P}{V^2} \cdot \frac{(1 + sin.\,\phi)^2}{sin.\,\phi} \ldots \qquad \ldots \qquad (15)$$

it follows that, with the same initial potential difference, the most economical current to employ is directly proportional to the power to be furnished at the distant end, the most economical resistance per mile to give to the conductor is inversely proportional, and the most economical sectional area directly proportional, to the power that has to be furnished at the distant end of the line.

VI. In the construction of telpher lines we use steel rods both to carry the load and to carry the conductor. In order, then, to see how the numbers in Table I. must be altered if steel be used instead of copper, we must see how the value of t is altered. Now, since

$$t^2 = 67{\cdot}84\,\frac{i \times c \times \rho}{p},$$

where i is the yearly interest, including depreciation, on money invested in conductors; c the value, in pounds, of a ton of the metal used in making the conductor, together with the value of the necessary amount of insulation; ρ the resistance of a wire one mile long and one square inch in section of the material employed

in making the conductor; and p the annual cost, in pounds, of an electric horse-power for the number of hours that power is required. Now the specific resistance of steel bears to the specific resistance of copper, approximately, the inverse ratio of the cost per ton of steel to the cost per ton of copper; hence the product $c\,\rho$ for steel will be roughly the same as the $c\,\rho$ for copper, and consequently the value of t may for a rough approximation be regarded as unaltered. All the columns, therefore, in Table I. will remain roughly the same if steel be used in place of copper, with the exception of column 7, giving the sectional areas, and column 8, the number of amperes per square inch.

Also all the columns will remain unaltered as long as $\frac{i \times c}{p}$ is constant; for example, no change will be necessary if the yearly interest, including depreciation, be taken as 10 per cent. instead of 15, and if the yearly value of an electric horse-power be also taken as £10 instead of £15.

VII. We may take as an example of the use of the results obtained by this investigation the case of the electric transmission of power from Paris to Creil by M. Deprez. The distance was $37\frac{1}{2}$ miles, and as a wire was used for both the going and return conductors, n equals 75; the potential difference at the dynamo (V) was about 5,600 volts, therefore

$$\begin{aligned} tan.\,\phi &= \frac{n\,t}{V} \\ &= 0{\cdot}2278, \\ \text{or } \phi &= 12^\circ\ 50'. \end{aligned}$$

Hence, as the power furnished at the distant end of the line (P) was about 30,000 watts,

$$\begin{aligned} C &= 6{\cdot}549 \text{ amperes}, \\ \text{and } r &= 2{\cdot}073 \text{ ohms}, \end{aligned}$$

give the values of the current and the resistance per mile of the line that should be used to give maximum economy; or, since the line is 75 miles long, the total resistance should equal 155·5 ohms.

M. Deprez actually used a current of about 7·2 amperes, and the total resistance of his line was 100 ohms. We do not know on what principle he calculated the size to give to his conductor,

which was a copper wire 5 millimètres in diameter, but the current conveyed was at the rate of about 36·6 amperes per square centimètre. The above, however, shows that the most economical current, using 17 for the value of t, would have been at the rate of 47·7 amperes per square centimètre. But as his object was rather to show economy in electric transmission of power, irrespective of first cost, than to show economy in copper used, and as when he began his experiments he was probably not quite sure of the potential difference at which his dynamo would give out electric power, we think that he was quite right in using a thicker conductor than our calculation shows would have produced the minimum total waste.

We have already seen that when we have to supply a given amount of electric power at the end of a certain line, using a given potential difference at the dynamo, the current-density to be employed to obtain maximum economy diminishes as the length of the line increases. Thomson's rule for the current-density is obtained from his equation for maximum economy—

$$C = \frac{t}{r},$$

and the equation

$$A = \frac{0{\cdot}04378}{r}$$

$$\therefore D = \frac{t}{0{\cdot}04378}, \text{ which is independent}$$

of the length of the line.

For t equal to 17 his D equals about 393 amperes per square inch. We see, therefore, that this current-density exceeds that given for all the lengths of line, even for the shortest—0·1 mile or 170 yards—in column 8 of Table I., although in calculating this table the same value was employed for t; that is, the same values were used for the yearly rate of interest, for the price of copper wire per ton, with its necessary insulation, and the same cost per year for an electric horse-power for the number of hours power is required. In order to see whether for any distance, or for any amount of electric power to be supplied at the end of this distance, it is economical to use so large a current-density as is given by Thomson's rule, we will find an expression for our

current-density. Dividing the expression given for C in (13) by that for A in (15), we have

$$D = \frac{V}{0{\cdot}04378\, n}\left(\frac{sin.\,\phi}{1 + sin.\,\phi}\right);$$

hence, as $$tan.\,\phi = \frac{n\,t}{V},$$

$$D = \frac{V}{0{\cdot}04378} \cdot \frac{t}{nt + \sqrt{n^2 t^2 + V^2}} \quad \ldots \quad (16)$$

Now this is independent of P, the number of watts to be supplied at the end of the line; hence all the values of D, in column 8, Table I., being smaller than the current-density given by Thomson's formula for maximum economy has nothing to do with the amount of power that is to be supplied. Further, we see that the value of D in (16) can only equal $\frac{t}{0{\cdot}04378}$, the value of D given above by Thomson's formula, when either V is extremely large or n extremely small. Hence we may conclude that *in all problems connected with the electric transmission of power where the maximum potential difference that we may use is fixed for us by the Board of Trade, or otherwise, a smaller current-density than that given by Thomson's formula must be used to obtain maximum economy, and the longer the line the smaller must this current-density be; also, the smaller the maximum potential difference that may be employed, the smaller must the current-density be to obtain maximum economy.*

VIII. We have discussed at some length the conditions of maximum economy when a given amount of power has to be supplied at a given distance with a given potential difference at the dynamo, on account of its wide practical importance; but there are many other practical cases which we have not thought it necessary to discuss in which there is an initial relation connecting C and r. One example may, however, be referred to.

Let there be a level electric railway extending n miles in one direction from the engine-house, on which one train is running requiring P watts to propel it at a uniform speed of v miles per hour. Let the resistance of the conductor conveying the power from the dynamo to the train be r ohms per mile, and let V be

the constant potential difference at the dynamo. At a time (τ) reckoned from the time the train is at the engine-house let it be at a distance x miles along the line, then

$$P = C\,(V - C\,x\,r),$$
$$x = v\,\tau,$$
$$d\,x = v\,d\,\tau.$$

When the train is at a distance x the rate of wasting power, in watts, is

$$C^2\,x\,r + n\,\frac{t^2}{r};$$

therefore the waste, in joules, in a time $d\,\tau$ is

$$\left(C^2\,x\,r + n\,\frac{t^2}{r}\right) d\,\tau;$$

hence the loss in the whole line n miles long is

$$\frac{1}{v}\int_0^n \left(C^2\,x\,r + n\,\frac{t^2}{r}\right) d\,x,$$

and maximum economy will be effected by selecting C and r so that this expression is a minimum when C and r are connected by the first equation given above.

IX. Hitherto we have been dealing with a conductor giving off power only at one point—either at its end, or, as in the last problem, at a point the position of which varies from time to time; but in telpherage, and in many systems of electric lighting and transmission of power, we have to deal with a conductor giving off in every mile the same amount of electric energy, which, bear in mind, does not mean giving off the same amount of current per mile, since there is a diminishing potential difference as we proceed along the conductor from the dynamo. This problem we deal more fully with in another paper. But if we suppose that an independent conductor takes the required supply of energy to every short length of line—that is, if a number of feeders are employed—we can at once use the results that we have already obtained to determine the most economical amount of copper to employ.

Having determined the most economical size of separate

conductor to convey the power to each point of the line of distribution, we may for practical purposes imagine all the conductors connected together metallically so as to form a tapered conductor. As, however—if we imagine such a metallic joining together of the separate conductors—currents will flow through the connections, because the potentials at a point where a connection is going to be made differ from one another in the various conductors, it follows that a conductor of the aggregate section of all the small conductors at every place will not be as economical as would be a conductor whose section at every place was independently determined from the considerations which are given by us in our other paper. However, taking the section of the tapered conductor to be equal to the sum of the sections of the separate conductors which distribute the energy with maximum economy, we find that the following is the result:—

Let the section of a conductor to transmit with maximum economy P watts n miles with a given potential difference be called

$$P\,f\,(n);$$

then

$$\int_{x}^{x_1} P\,f\,(x)\,d\,x$$

is the aggregate section at a point x miles from the dynamo when the end of the line is x_1 miles from the dynamo. It is easy to obtain an exact integral, using (15) for $P\,f\,(x)$, but we have preferred to integrate from a curve giving the value of A or $P\,f\,(x)$ when P is 20,000 in column 7 of Table I.

In this way we have, for the purposes of illustration, calculated Table II., which gives the most economical sectional area, in square inches, at the end of each mile when the conductor *tapers* according to the law just mentioned; it is calculated for a potential difference of 200 volts at the engine-house, and for a power of 5,000 watts given off in every mile. The four horizontal rows give the sectional area, in square inches, of the tapered conductor at the end of each mile, when the total length of the conductor is respectively 3, 5, 8, and 10 miles.

Table II.

Total Length of Conductor from Engine-House, in miles.	Area, in square inches, of the Tapering Conductor at the end of										
	0	1	2	3	4	5	6	7	8	9	10 miles.
3	0·24	0·17	0·09	0							
5	0·47	0·40	0·32	0·23	0·12	0					
8	0·94	0·88	0·79	0·70	0·60	0·47	0·33	0·18	0		
10	1 35	1·28	1·20	1·11	1·00	0·88	0·74	0·58	0·41	0·21	0

Table III. gives the current, in amperes, flowing through the conductor at the end of each mile in each of the various cases described above.

Table III.

Total Length of Conductor from Engine-House, in miles.	Current, in amperes, flowing through the Tapering Conductor at the end of										
	0	1	2	3	4	5	6	7	8	9	10 miles.
3	85·7	59·6	31·4	0							
5	151·8	125·7	97·5	66·1	34·0	0					
8	262·9	236·8	208·6	177·2	145·1	111·1	75·5	38·4	0		
10	343·2	317·1	288·9	257·5	225·4	191·4	155·8	118·7	80·3	40·7	0

Table IV. gives the current-density at the end of each mile in each of the cases described above.

Table IV.

Total Length of Conductor from Engine-House, in miles.	Current-Density in the Tapering Conductor at the end of										
	0	1	2	3	4	5	6	7	8	9	10 miles.
3	357·2	350·5	348·9	0							
5	322·9	314·2	304·7	287·4	283·2	0					
8	279·7	269·1	264·1	253·1	241·8	236·3	228·8	213·3	0		
10	254·2	247·7	240·7	232·0	225·4	217·5	210·5	204·6	195·8	193·8	0

Here again, then, the current-density proper to be used to obtain maximum economy is not constant. It not only diminishes as we go further along the tapered conductor, but at any one point is the less the greater the total length of the line.

Professor GEORGE FORBES: The paper which has just been read will greatly assist all persons who, like myself, have much to do with the calculation of the size of conductors, and especially for the transmission of power. The general formulæ which the authors publish will save much calculation in special cases. I object to the way in which Sir William Thomson's name has been introduced. The problem now before us is a totally different one to that which he published in his celebrated paper in 1881. In every case where we apply Thomson's law we must do so very guardedly, and we should check our result by making sure that a slight change in the size of conductors does not produce greater economy. Professor Forbes.

The tables which are given in the paper serve only to illustrate its principles, and will not be applicable to special cases.

In electric lighting these formulæ do not apply, because we may have what pressure we please in the mains, and the current is known, and there is no great fall of potential in the district of supply.

Mr. R. E. CROMPTON: I can only re-echo the remark of Professor Forbes as regards the great pleasure with which I have listened to Professors Ayrton and Perry's extremely useful paper. Professor Forbes has anticipated my remarks upon several points; but I wish to remind the authors of a case which very frequently presents itself to electric light engineers. When it is desired to supply distant centres of distribution from a generating station by means of feeder mains, the amount of current required at these distant centres is fixed for us by the demands of the houses. Of course it must not exceed a certain maximum. The E.M.F. at the distant centre must be kept constant by means of automatically or in other ways varying the E.M.F. at the dynamo end. Mr. Crompton.

What we require for this purpose is a ready method of calcu-

Mr. Crompton.

lating, not the most economical current combined with the most economical section of conductor—for, as above said, we can have no control over the current—but the most suitable fall of E.M.F. to allow, combined with the most economical section of conductor.

I can corroborate Professor Forbes's remark that never at any time was there any intention on the part of the Board of Trade to limit the E.M.F. to 200 volts at the dynamo end. This limit was fixed as between the terminals in the houses.

Professor AYRTON: The dynamo itself limits the potential; you must have a dynamo of some potential.

Mr. CROMPTON: Yes, certainly; but the Board of Trade limit only applied to houses.

Professor AYRTON: No; it also applies to electric railways. But apart from the Board of Trade limit the dynamo has a certain difference of potential.

Mr. CROMPTON: Why should it have a fixed difference?

Professor AYRTON: There is some difference of potential if there is a dynamo.

Mr. CROMPTON: Not at all. I propose to let the dynamo supply a current at any difference of potential that may be required at its terminals in order to obtain 200 volts at the far end of the main, and to vary the speed of the dynamo, and hence the potential, in order to make the difference of potential at the far end constant. I have been trying to work out the figures in the paper showing that with 333 ampères at the dynamo end × 200 volts, in order to get a delivery of 10,000 watts at the far end, there is only a waste of 5,660 watts. I make the waste to be just ten times that amount. There is evidently a mistake in the position of the decimal point; at least, I think so. ·051 ohm has been taken as the total resistance, whereas it should have been ·51 ohm.

Dr. Fleming

Dr. J. A. FLEMING: This interesting paper appears to me to require more time to consider than we have at present had, before venturing to criticise it at all fully. I concur with the remarks of the previous speakers, and feel that the paper distinctly marks a valuable addition to our knowledge upon the subject. It may seem, perhaps, rather ungracious, when we have had so much infor-

mation given us, to complain that we have not had more; but still Dr. Fleming I venture to think that, in spite of all that has been said and written as to the size of conductors to be used in different cases, we are still at a loss for information to guide us in many cases that present themselves in actual practice. The difficulty is, I think, chiefly because some of the quantities that are generally taken as constant are variable, while many that are taken as variable are to a great extent fixed for us. Perhaps the most important case that arises in distributed lighting is in the case of central station lighting. In such a case the maximum current is fixed directly the number of lamps to be supplied is known. Take, for instance, a case which occurs in practice. Suppose an installation is required for a given area. The first constant to be obtained is the number of lamps to be taken in different spots; then another constant—which is generally very soon fixed upon—is the position of supply. Now the kind of case we are dealing with in practice, and which certainly does require help from theory more than is already possessed, is the case of an area where the point of supply is fixed, and where the number of lamps promised to be taken in different positions is fixed. Let us suppose a line upon which lamps are located at different places, and that the line is fed at different places: the problem which presents itself is to calculate the sizes of these feeders. I have always found one difficulty in dealing with Sir William Thomson's law, and that is, that it gives different current-densities according to the percentage of cost which the taking up and laying down of the streets is, of the whole cost of the cable. The total cost of the conductors, according to Sir William Thomson's law, must be taken as meaning, not merely the cost of the copper, but that of the whole conductor installation, taking up the streets, making good all works, and every penny put into the conductor system from the time of making out the tender to the time the streets are passed by the surveyor; and that is the sum on which interest has to be taken. Now it is easily seen that in two cases where the total supply of current is the same, but in which the proportion of cost of copper to total cost of laying mains is different, the rule will

Dr. Fleming give us very different current-densities in the mains; and it hardly seems to me that this is a safe practical rule to follow. However, the table and formulæ which Professors Ayrton and Perry have given us will no doubt help in a great many cases. There remains, however, much to be done before we can find guidance in theory to what is perhaps the most ordinary case in practice; and one thing that I should like to have further information about is whether, in the case I have sketched out, the laws already given, enable us to see what ought to be exactly the size of the feeders when it is known what proportion the copper will be of the whole cost of putting down the installation.

The PRESIDENT: As time is pressing, I will ask Professor Ayrton to reply.

Professor Ayrton. Professor AYRTON: Mr. Crompton is mistaken in thinking that there is any such numerical error in our paper as he has referred to. The mistake into which he has been led in the hurry of the moment arises from his not having noticed that the waste is in all cases calculated *per mile*, not for the whole length of the line. The word "total" employed in the paper is perhaps a little misleading, but it refers to the sum of the waste from the two causes—heating of the conductors and interest on capital expended in conductors—and has no reference to the waste along the whole line. As to the Board of Trade limit only applying to houses, and not to the mains, I may instance the rules laid down by the Board of Trade with reference to the Portrush Railway, and which limit the potential difference at the Bushmills, or dynamo, end of the line even when the car requiring the power may be at the other end of the railway, six miles away; hence in such problems of electric transmission we have a maximum potential difference settled for us.

We are all of us much indebted to Sir William Thomson for his remarkable paper given at the meeting of the British Association in 1881, since it possessed a double value. First, it directed the attention of electrical engineers to the importance of determining the conditions of maximum economy when we had a choice of expenditure in two directions of such a nature that increasing the one expenditure diminished the other; for example, it was

this paper of Sir William Thomson's that suggested to my colleague and myself the method which we published about a year ago for determining what was the most economical potential difference to use with a certain type of incandescent lamps. Secondly, this paper of Sir W. Thomson's showed us how to determine the most economical gauge to give to a wire when we knew the current, the yearly value of a horse-power, the value of copper, and the rate of interest on money. But what we have desired to point out in our paper is that, although his rule is perfectly correct mathematically, it cannot generally be used to determine the conditions of maximum economy, because some electrical condition, either in addition to the strength of the current or in place of the strength of the current, is given us. Indeed, in the application made by Sir William Thomson of his own rule in his inaugural address, he *starts* by assuming that we know the potential difference at the dynamo end of the line, which he takes as 80,000 volts. He next says, "Let us employ a solid copper wire half an inch in diameter," &c. Professor Ayrton.

To obtain the most economical current he uses his rule

$$C = \frac{t}{r};$$

and as 48·85 is the value he takes for t, and 0·2035 ohm the value he takes for r, the resistance per mile of his conductor, half an inch in diameter, he concludes that the proper value to give to C is 240 amperes.

But we deferentially submit that this is incorrect, because, as we have pointed out, his rule has been obtained by finding the value of r that makes the total waste per mile,

$$C^2 r + \frac{t^2}{r},$$

a minimum when C is constant and r is variable; and it cannot, therefore, be used to find the value of C when r is fixed and C is the variable, which are the conditions of Sir William's Niagara problem as he has stated it. In fact, if we regard r as constant and C as the variable, the value of C that makes the expression for the total waste a minimum is C equal to nought. And it is perfectly true that C equal to nought leads in this case to

Professor Ayrton.

minimum waste, but not, of course, to maximum economy. In fact, when C alone is the variable, a consideration of the waste does not lead to a practicable answer, and consequently with the conditions that Sir W. Thomson has taken with the Niagara problem a method of procedure different from the one that he has adopted must be followed in order to determine the value of C that should be used to obtain maximum economy.

In the problem solved in our paper we have considered that the power given out at the other end of the line was fixed, but a this is not one of the conditions of the Niagara problem, the method followed in our paper cannot in this case be employed either. Probably the simplest way of attacking the Niagara problem is to determine the value of C that makes the *efficiency a maximum.* This may be done as follows:—If V is the potential difference at the dynamo, n the length of the line in miles, then the power in watts received at the far end is

$$C\,(V - C\,n\,r),$$

and the power put into the line in watts equals

$$C\,V + n\,\frac{t^2}{r},$$

the second term in this latter expression representing the power used up in the form of interest on the capital which has been expended on the conductor. Hence the efficiency equals

$$\frac{C\,(V - C\,n\,r)}{C\,V + n\,\dfrac{t^2}{r}}.$$

Differentiating with respect to C, and equating to nought, we find that

$$C = \frac{t}{r} \cdot \frac{\sqrt{n^2\,t^2 + V^2} - n\,t}{V}$$

makes the efficiency a maximum.

Hence we see that $\frac{t}{r}$, as given by Sir William Thomson, must be multiplied by the factor

$$\frac{\sqrt{n^2\,t^2 + V^2} - n\,t}{V},$$

a factor depending on the length of the line and on the

potential difference at the dynamo, in order to obtain the proper value of C. For V equal to 80,000 volts, and n equal to 300 miles, this factor becomes Professor Ayrton.

$$0{\cdot}8333;$$

so that with the 300 miles of conductor half an inch in diameter the proper current to employ with the particular number of hours of working, the cost of copper, the rate of interest on money, and the yearly value of a horse-power at Niagara taken by Sir W. Thomson, is, we submit, not 240 amperes, as adopted by Sir William Thomson in his inaugural address, but

$$240 \times 0{\cdot}8333,$$

or 200 amperes,

in order to obtain maximum economy.

Professor PERRY: Might I be allowed to say a word or two? I think that Professor Forbes did not quite understand the paper in one important respect, and it may be well to explain further. Take it that Sir William Thomson solved a certain problem, viz., "Given a certain difference of potentials, say at Niagara, a certain power to be delivered at Philadelphia"—— Professor Perry.

Professor FORBES: That was not it.

Professor PERRY: He did assume some potential, because he had to assume a maximum potential which he could use with reasonable insulation; he assumed, at all events, 80,000 volts in the Niagara problem, and all I ask is that you assume something. Take any case of power transmission finished by Thomson's rule—any case whatever—and our rule will give you greater economy. You may use as high a potential as you please, but you have some limit, and we take your potential, whatever it may be. Suppose we take Sir William's 80,000 volts——

Professor FORBES: That did not enter into the question of the paper dealing with the economy of conductors.

Professor AYRTON: But he did in his extremely interesting inaugural address.

Professor FORBES: That was in a different paper.

Professor PERRY: Suppose the case of delivering a certain amount of power to a place. You must have some current flowing

Professor Perry. through the conductor, and must assume some power flowing in at the dynamo end.

Professor FORBES: I quite agree that if you have the power at the far end fixed, the second statement of Thomson's law is inapplicable, and only the first statement of that law applies.

Professor PERRY: Very well; that is all that I have been contending for.

The PRESIDENT: We have had a most interesting discussion on the paper. I was afraid at one time that I should have to call some of the members to order, but it has passed off very well. Professor Ayrton has attacked the question from a different point to what I have seen before, and we have had an interesting mathematical paper upon it.

The following paper was then read:—

UNIFORM DISTRIBUTION OF ELECTRIC POWER FROM A UNIFORM CONDUCTOR.

By Professors W. E. AYRTON, F.R.S., and JOHN PERRY, F.R.S.

I. For telpher lines of about two miles long, with a potential difference (or what we shall, for the sake of brevity, call a P.D.) of 200 volts at the dynamo, the flexible rod which carries the telpher train is found to act quite efficiently as the conductor of electricity, even when there are so many trains on the line that the distance from the centre of one to the centre of the next is as little as 400 feet. Of course, when the support is a stiff rail, and is, therefore, of much greater section than the rod in question, a telpher line of much greater length than two miles can be employed without any separate conductor being used to assist the carrying rail in conveying electric power. The P.D. varies, of course, along the line, but as we have a peculiar form of electric governor attached to all our telpher locomotives, which causes each train to always go at approximately the same speed, independently of the P.D. at its terminals, and without the employment of a brake, and without the consequent waste of electric energy, each train may be regarded as requiring approximately always the same supply of power; and, as the telpher

trains are spaced fairly evenly over the line, a telpher line may be considered as a conductor from which the same amount of power has to be given off per quarter mile. Hence the problem of transmitting electric power by a rod of uniform section, where a certain amount of power is required to be taken from the rod in every quarter mile, is one which we have found it necessary to investigate for the purpose of making calculations on telpherage. The problem may be stated thus :—

A conductor whose resistance per mile is r ohms dispenses electric power of the amount P watts per mile throughout its length to motors in parallel. When the P.D., either at the dynamo end or at the remote end, is given, to find what is the current flowing, and what is the P.D. at every part of the line.

It simplifies our ideas to regard the earth as a return conductor of no resistance and of zero potential, and in what follows one mile of our conductor will mean one mile of the sum of the going and return conductors. At a place x miles from the end of the line remote from the engine-house let C be the current in amperes, and V the potential difference between the conductor and the earth in volts, then

$$V \frac{dC}{dx} = P \quad \dots \quad \dots \quad \dots \quad (1)$$

and as

$$C = \frac{1}{r} \frac{dV}{dx} \quad \dots \quad \dots \quad (2)$$

we find

$$\frac{d^2 C}{dx^2} + \frac{r}{P} C \left(\frac{dC}{dx}\right)^2 = 0 \quad \dots \quad \dots \quad \dots \quad (3)$$

the solution of which is

$$x = \int \epsilon^{\frac{r}{2P} C^2 + \text{const.}} \, dC \quad \dots \quad (4)$$

and which furnishes the general equation connecting x and C. As there is no general solution of (4) we are compelled to fall back upon approximate solutions.

II. First approximate solution :—

Assume that, instead of the power dispensed per mile being constant, the current leaving the conductor per mile is constant; that is, let

$$\frac{dC}{dx} = a \quad \dots \quad \dots \quad \dots \quad (5)$$

where a is constant throughout the line. Then, since C equals nought when x equals nought,

$$C = a\,x \quad \dots \quad \dots \quad \dots \quad (6)$$

and from (2) and (6) we have

$$\frac{d\,V}{d\,x} = r\,a\,x,$$

so that

$$V = V_0 + \frac{r\,a}{2}\,x^2 \dots \quad \dots \quad (7)$$

where V_0 is the P.D. at the distant extremity of the line.

The amount of inaccuracy arising from making the assumption that the current dispensed per mile instead of the watts is constant, is seen from taking a practical example. Let r equal 1 ohm per mile, V_0 equal 200 volts, a equal 25 amperes per mile, then (5), (6), and (7) become

$$\frac{d\,C}{d\,x} = 25$$

$$C = 25\,x$$

$$V = 200 + \frac{25}{2}\,x^2$$

The following table (I.) shows V, the volts, and P, the watts, dispensed per mile for various values of x, P being calculated from (1):—

Table I.

x.	V.	P.
0	200	5,000
1	212·5	5,312·5
2	250	6,250
3	312·5	7,812·5
4	400	10,000

From Table I. it is evident that the assumption (6) is not as likely to give a good working formula as

$$C = \frac{a\,x}{1 + s\,x} \quad \dots \quad \dots \quad \dots \quad (8)$$

from which we obtain

$$V = V_0 + \frac{r\,a}{s}\left\{x - \frac{1}{s}\,log.\,(1 + s\,x)\right\} \quad \dots \quad (9).$$

We have found, however, that still greater accuracy is obtained by making the assumption

$$C = \frac{2\,a}{r}\frac{x}{1 + s\,x^2} \qquad \dots \qquad \dots \quad (10)$$

so that

$$V = V_0 + \frac{a\,x^2}{1 + s\,x^2} \qquad \dots \qquad \dots \quad (11)$$

The assumption

$$C = a\,x - b\,x^3 \quad \dots \qquad \dots \qquad \dots \quad (12)$$

we have also made use of in our practical work, but the best working formula which we have yet obtained is what we call our

III. Second approximate solution. This consists in assuming that

$$C = a\,x - b\,x^c, \qquad \dots \qquad \dots \qquad \dots \quad (13)$$

from which we obtain

$$\frac{d\,C}{d\,x} = a - b\,c\,x^{c-1}$$

$$\frac{1}{r}\,\frac{d\,V}{d\,x} = a\,x - b\,x^c$$

$$\therefore V = V_0 + \frac{r\,a}{2}\,x^2 - \frac{r\,b}{c + 1}\,x^{c+1} \qquad \dots \quad (14)$$

Taking as an example r equals 1 ohm, V_0 equals 100 volts, at three points x equals 0, x equals 1, and x equals 1·5, let P or

$$V\,\frac{d\,C}{d\,x} = 10{,}000 \text{ watts};$$

then it is evident that $a = 100$,

and we find that

$$5{,}000 - 150\,b\,c + \frac{b\,c - 100\,b}{c+1} = 0 \qquad \dots \quad (15)$$

$$\left\{100 - b\,c\left(\frac{3}{2}\right)^{c-1}\right\}\left\{212{\cdot}5 - \frac{b}{c + 1}\left(\frac{3}{2}\right)^{c+1}\right\} - 1{,}000 = 0. \quad (16)$$

The values of b and c which satisfy equations (15) and (16) may be found by the use of squared paper to any degree of accuracy we please. We have roughly found the values—

$$b = 14{\cdot}75$$

$$c = 2{\cdot}115$$

so that

$$C = 100\,x - 14{\cdot}75\,x^{2{\cdot}115} \qquad \dots \qquad \dots \quad (17)$$

From this formula we have calculated the following table for C:—

Table II.

x.	*C*.	*x*.	*C*.
0	0	·9	78·20
·1	9·89	1·0	85·25
·2	19·51	1·1	91·96
·3	28·84	1·2	98·31
·4	37·86	1·3	104·31
·5	46·59	1·4	109·95
·6	56·99	1·5	115·23
·7	63·67	1·6	120·14
·8	70·80	1·7	124·69

IV. Third approximate solution:—

Assume that C can be expanded in powers of x, then we find that the solution may be put in the form

$$C = \sqrt{\frac{P}{r}} \times \phi(y) \quad \dots \quad \dots \quad (18)$$

$$V = V_0 \times \psi(y) \quad \dots \quad \dots \quad (19)$$

where
$$y = \frac{rP}{V_0^2} x^2,$$

and $\phi(y) = \sqrt{y}\,(1 - \frac{1}{6} y + 0{\cdot}05833\, y^2 - 0{\cdot}0252\, y^3 + 0{\cdot}01204\, y^4 + \text{\&c.}) \quad \dots \quad \dots \quad \dots \quad (20)$

$$\psi(y) = 1 + 0{\cdot}5\, y - 0{\cdot}0415\, y^2 + 0{\cdot}009722\, y^3 - 0{\cdot}00315\, y^4 + 0{\cdot}001204\, y^5 - \text{\&c.} \quad \dots \quad (21)$$

For some time we have relied in our telpherage calculations on a table of values calculated from (20) and (21) for values of y from 0 to 1; but the fact that it was possible to express C and V in terms of y, so that only one table of values of ϕ and ψ was needed for calculation, gave us a new direction, and led us to investigate how far the assumptions contained in (18) and (19) were really true in all cases.

From (3) we have

$$\frac{dC}{dx} = \epsilon^{-2\frac{r}{P}C^2 - \text{const.}} \quad \dots \quad \dots \quad (22)$$

and when
$$C = 0$$

$$V_0 \frac{dC}{dx} = P.$$

$$\therefore \text{the constant} = \log. \frac{V_0}{P}$$

Hence (4) may be written—

$$x = \frac{V_0}{P}\int \epsilon^{\frac{r}{2P}C^2} dC. \quad \dots \quad \dots \quad (23)$$

Now let $$y = \frac{rP}{V_0^2}x^2$$

and $$z = \frac{r}{P}C^2$$

then $$\frac{dy}{dz} = \sqrt{\frac{y}{z}}\,\epsilon^{\frac{z}{2}},$$

hence z must be a function of y, say $\phi(y)$

$$\therefore C = \sqrt{\frac{P}{r}} \times \phi(y) \text{ in all cases;}$$

and since, from (1), $V\dfrac{dC}{dx} = P$,

it follows that $V = V_0 \times$ some function of y, say $\psi(y)$,

or $V = V_0 \times \psi(y)$ in all cases.

V. As the laws (18) and (19) are, therefore, always true, it is obvious that if we obtain a table of the values of C and of V for various values of x, using any values of V_0, r, and P whatever, this table will enable us to calculate the values of $\phi(y)$ and of $\psi(y)$, and therefore the values of C and V for any other values of V_0, r, and P.

It is obvious that for any short length of a telpher line we may assume the law $\dfrac{dC}{dx}$ is constant,

or $$C = C_1 + \frac{P}{V_1}(x - x_1) \quad \dots \quad \dots \quad \dots \quad (24)$$

and $$V = V_1 + C_1 r(x - x_1) + \frac{rP}{2V_1}(x - x_1)^2 \dots \quad (25)$$

where C_1 and V_1 are the current and P.D. at a point whose distance from the end of the line remote from the engine-house is x_1 miles.

Taking $P = 10{,}000$ watts,

$r = 1$ ohm,

$V_0 = 100$ volts;

and taking $x_2 - x_1 = 0{\cdot}1$ mile in every case,

we have $$C_2 = C_1 + \frac{1000}{V_1} \dots \quad \dots \quad \dots \quad (26)$$

and $$V_2 = V_1 + \frac{C_1}{10} + \frac{50}{V_1} \quad \cdots \quad \cdots \quad (27)$$

From (26) and (27) we have, step by step, calculated the following table:—

Table III.

x.	*C*.	*V*.	*y*.	ϕ (*y*).	ψ (*y*).
0	0	100	0	0	1
·1	10	100·5	·01	·1000	1·005
·2	19·95	102·5	·04	·1995	1·025
·3	29·706	104·98	·09	·2971	1·0498
·4	39·232	108·43	·16	·3923	1·0843
·5	48·454	112·81	·25	·4845	1·1281
·6	57·318	118·103	·36	·5732	1·1810
·7	65·785	124·26	·49	·6578	1·2426
·8	73·832	131·24	·64	·7383	1·3124
·9	81·451	139·00	·81	·8145	1·3900
1·0	88·645	147·51	1·00	·8864	1·4751
1·1	95·424	156·71	1·21	·9542	1·5671
1·2	101·805	166·57	1·44	1·0180	1·6657
1·3	107·008	177·05	1·69	1·0701	1·7705
1·4	112·656	188·04	1·96	1·1265	1·8804
1·5	117·974	199·57	2·25	1·1797	1·9957
1·6	122·980	211·61	2·56	1·2298	2·1161
1·7	127·705	224·15	2·89	1·2771	2·2415
1·8	132·166	237·14	3·24	1·3217	2·3714
1·9	136·383	250·57	3·61	1·3638	2·5057
2·0	140·373	264·41	4·00	1·4037	2·6441

VI. As the importance of this Table III. grew upon us, and as such a step by step method as we have employed in calculating it might introduce accumulative errors, we saw the necessity of obtaining some independent check of its accuracy. Until we became aware of the general truth of (18) and (19), the importance of only one table, such as III., did not suggest itself. But when it became evident that one such table was alone necessary for all

calculations, we felt it desirable to obtain a check of its accuracy. We have therefore for the above values,

$$P = 10{,}000 \text{ watts},$$
$$r = 1 \text{ ohm},$$
$$V_0 = 100 \text{ volts},$$

obtained the approximate values of $\int \epsilon^{\frac{r}{2P}C^2} dC$ which are given in Table IV.

In Table V. we have obtained the values of $r\int C\,dx$ to obtain V, and from the values of x, C, and V we have recalculated y, $\phi(y)$, and $\psi(y)$. The near equality of the numbers given in Tables III. and V. show that if such small intervals as δx equals 0·05 mile be taken, either method of calculation will give nearly identical results.

Table IV.

$C.$	$\epsilon^{\frac{C^2}{20{,}000}}$	$\int \epsilon^{\frac{C^2}{20{,}000}} dC.$	$x.$
0	1		0
10	1·0050	10·025	·1002
20	1·0202	20·152	·2015
30	1·0460	30·482	·3048
40	1·0833	41·128	·4113
50	1·1331	52·210	·5221
60	1·1972	63·861	·6386
70	1·2776	76·235	·7623
80	1·3771	89·508	·8951
90	1·4993	103·890	1·0389
100	1·6487	119·630	1·1963
110	1·8312	137·029	1·3703
120	2·0544	156·457	1·5646
130	2·3280	178·369	1·7836

Table V.

x.	C.	$\int C\,dx$.	V.	y.	$\phi(y)$.	$\psi(y)$.
0	0	0	100·	0	0	1·000
·1	9·975	4·988	100·50	·01	·0997	1·005
·2	19·853	14·914	101·99	·04	·1985	1·020
·3	29·547	24·700	104·46	·09	·2955	1·045
·4	38·940	34·243	107·88	·16	·3894	1·079
·5	48·006	43·473	112·23	·25	·4801	1·122
·6	56·686	52·346	117·50	·36	·5669	1·175
·7	64·961	60·823	123·54	·49	·6496	1·235
·8	72·836	68·898	130·43	·64	·7284	1·304
·9	80·342	76·589	138·09	·81	·8034	1·381
1·0	87·295	83·818	146·50	1·00	·8729	1·465
1·1	93·880	90·587	155·53	1·21	·9388	1·555
1·2	100·224	97·052	165·24	1·44	1·0022	1·652
1·3	106·095	103·159	175·55	1·69	1·0609	1·755
1·4	111·650	108·872	186·44	1·96	1·1165	1·864
1·5	116·772	114·211	197·86	2·25	1·1677	1·979
1·6	121·687	119·229	209·79	2·56	1·2169	2·098

Although a table of the values of $\phi(y)$ and $\psi(y)$ suffices for our practical needs, it is desirable to obtain a formula that will nearly represent these values. This may be obtained by using (13), if (13) be sufficiently accurate. To test the accuracy of (13), we see, taking a as equal to 100, that *log.* $(100\,x - C)$ and *log.* x, when plotted, should give a straight line. Using the values of x and C given in Table V., we have plotted this line, and find that for the smaller values of C it is quite straight, and even for higher values of C the curvature is not very perceptible.

Taking the straight line which lies most evenly among the points, we find that

$$log.\,(100\,x - C) = 1{\cdot}095 + 2{\cdot}697\ log.\,x,$$

so that
$$C = 100\,x - 12{\cdot}45\,x^{2{\cdot}697},$$

or
$$\phi(y) = \sqrt{y}\,(1 - {\cdot}1245\,y^{0{\cdot}8485}) \quad \ldots \quad (28)$$

Integrating $r\,.\,C\,.\,d\,x$ to obtain V, we find that

$$\psi(y) = 1 + \tfrac{1}{2}\,y - {\cdot}03367\,y^{1{\cdot}8485}. \quad \ldots \quad (29)$$

VII. We shall now proceed to discuss the efficiency of the

uniform delivery of power with a uniform conductor. The total loss of power in heat in n miles of the conductor is

$$\int_0^n C^2 r\, d x,$$

and the power utilised in the same length of line is

$$n P,$$

so that

$$\frac{1}{n P} \int_0^n C^2 r\, d x \quad \ldots \quad \ldots \quad (30)$$

(which we may call f) is the ratio of the total power wasted to the total power utilised. The reciprocal of $1 + f$ is what is usually called the efficiency (e), being the ratio of the power utilised to the total power given out by the dynamo.

Now, writing for C its value given by (18), we find that

$$f = \frac{1}{n} \int_0^n \phi^2 (y) \,.\, d x$$

which

$$= \frac{V_0}{2 n \sqrt{r P}} \int_0^{y_n} \frac{\phi^2 (y)}{\sqrt{y}} d y \ldots \quad \ldots \quad (31)$$

if

$$y_n = \frac{r P}{V_0^2} n^2$$

or

$$f = \frac{1}{2 \sqrt{y_n}} \int_0^{y_n} \frac{\phi_1 (y)}{\sqrt{y}} \,.\, d y. \ \ldots \quad \ldots \quad (32)$$

Hence f is really a function of y_n—that is, of the y corresponding with n miles, the length of the conductor. Hence also e or $\frac{1}{1 + f}$, the efficiency, is also merely a function of y_n.

In the following table (VI.) the values of $\phi (y)$ and $\psi (y)$ have been obtained by comparing the values given in III. and V., and e has been calculated as follows:—In (31) the approximate value of $\phi (y)$ given by (28), viz.,

$$\phi (y) = \sqrt{y} - 0{\cdot}1245\, y^{1{\cdot}3485}$$

has been substituted; then, on integrating, it is easy to show that

$$f = \tfrac{1}{3} y - 0{\cdot}053\, y^{1{\cdot}8485} + 0{\cdot}00242\, y^{2{\cdot}697} \quad \ldots \quad (33)$$

from which e or $\frac{1}{1 + f}$ has been determined.

Table VI.

y.	$\phi(y)$.	$\psi(y)$.	e.
0	0	1·000	1
·01	·100	1·005	·9975
·04	·200	1·022	·9881
·09	·300	1·047	·9718
·16	·400	1·090	·9514
·25	·500	1·125	·927
·36	·570	1·180	·8994
·49	·670	1·240	·87
·64	·733	1·308	·8383
·81	·809	1·390	·8079
1·00	·880	1·470	·7783
1·21	·950	1·561	·7416
1·44	1·010	1·660	·719
1·69	1·065	1·762	·695
1·96	1·121	1·872	·672
2·25	1·173	1·990	·6458
2·56	1·223	2·107	·6246
2·89	1·277	2·241	·6003
3·24	1·322	2·371	·5804
3·61	1·364	2·506	·562

VIII. We think that it has not yet been noticed that with a conductor of a given size transmitting a definite amount of power (P watts) to a motor, with a given P.D. at the dynamo, it is not only not possible to work beyond a certain distance, but it is not possible to have less than a certain electric efficiency in the transmission. For

$$P = C\,(V_1 - C\,n\,r) \quad \ldots \quad \ldots \quad \ldots \quad (34)$$

if V_1 is the P.D. at the dynamo and n is the length of the line in miles;

so that $$C = \frac{V_1 \pm \sqrt{V_1^2 - 4\,n\,r\,P}}{2\,n\,r}. \quad \ldots \quad \ldots \quad (35)$$

Hence the length of the conductor cannot exceed

$$n = \frac{V_1^2}{4\,r\,P} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (36)$$

and when this is the case the loss in the conductor

$$C^2 n r = \frac{V_1^2}{4 n r}$$

since, when n has the value given by (36),

$$C = \frac{V_1}{2 n r}$$

But when C has this value

$$P = \frac{V_1^2}{4 n r}$$

or the power lost equals the power transmitted, and the electric efficiency of the transmission equals one-half. Disregarding, then, the loss of power in the dynamo and motor, and confining ourselves to the power lost in the conductor alone, we may therefore conclude that *it is impossible to transmit power electrically to such a distance that the electric efficiency is less than one-half, or in all cases of electric transmission of power there must be at least an electric efficiency of one-half as far as the conductor is concerned.*

IX. Just as in the simple case of power transmission along a line of definite length, so with a telpher line where the power is given off all along the line, there is a limiting length of line for given values of P, V_1, and r. As the conditions have required careful study, we shall first discuss them in the simple form obtained by assuming that the current given off per mile is a constant (a), and afterwards, in XI., take the case where the power, and not the current given off per mile, is the constant.

If V_1 is the P.D. at the dynamo end, V_0 that at the distant end, n the length of the line, and r the resistance per mile,

$$V_1 = V_0 + \int_0^n a r x \, d x$$

$$= V_0 + \tfrac{1}{2} a r n^2;$$

also $$P = a V_0$$

hence $$2 V_0 = V_1 + \sqrt{V_1^2 - 2 r n^2 P} \qquad \ldots \quad (37)$$

$\therefore$ $$n = \frac{V_1}{\sqrt{2 r P}} \qquad \ldots \quad \ldots \quad \ldots \quad (38)$$

gives the limiting length of the line beyond which power cannot be transmitted and distributed.

To illustrate this better we may take the following example:—

Let
$$V_1 = 200 \text{ volts},$$
$$r = \tfrac{1}{2} \text{ mile},$$
$$P = 2{,}000 \text{ watts};$$

consequently, from (38), if n exceeds $\sqrt{20}$, the value of V_0 becomes unreal. In fact, since from (37)

$$V_0 = 100\left(1 \pm \sqrt{1 - \frac{n^2}{20}}\right),$$

if all possible values of V_0 and n be plotted as co-ordinates of points on squared paper, the points lie on an ellipse, as in Fig. 1.

For any value of n less than the limiting value there are two values of V_0 that satisfy the equation; thus, let $O\,P$ be such a value of n, O being the position of the dynamo, and P the end of the line remote from the dynamo, then $P\,Q$ or $P\,S$ are the values of V_0, and, since the P.D. at any point

$$V = V_0 + \tfrac{1}{2}\,a\,r\,x^2,$$

where x is the distance in miles of that point from P, we have either $Q\,R$ or $S\,R$ as the diagram of P.D. along the line, being the curves which satisfy this equation.

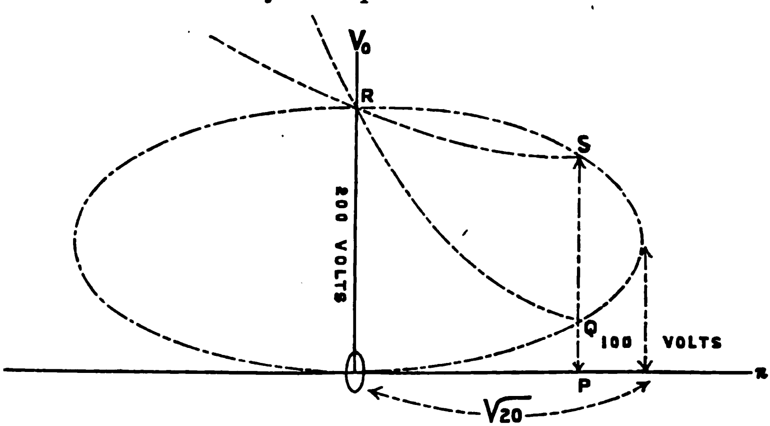


Fig. 1.

At the commencement of this paper it is stated that the motors which propel the telpher locomotives are governed so as to use approximately the same amount of power whatever be the P.D. at their terminals, and this governing is effected by the circuits being broken when the speed becomes too great. The

effect, then, of the governor coming into action is to raise the P.D. between the conductor and the earth, and consequently, when power is again supplied to the motor on the governor completing the circuit, when the speed falls the P.D. between the terminals of the motor commences by being higher than it was before the circuit was broken. It appears, therefore, that with such governors the condition of things represented by the curve $Q\,R$ will be unstable, and consequently that the motors will work with the higher potential differences represented by the curve $S\,R$.

X. We shall next consider what is the efficiency of uniform distribution of power when the length of the line is the maximum given by (38) for the given values of P_1, V_1, and r. From the equations given in Section IX. we have

$$a = \frac{1}{r\,n^2}\left(V_1 - \sqrt{V_1^2 - 2\,r\,n^2\,P}\right), \quad \ldots \quad \ldots \quad (39)$$

and

$$C = \frac{x}{r\,n^2}\left(V_1 - \sqrt{V_1^2 - 2\,r\,n^2\,P}\right). \quad \ldots \quad \ldots \quad (40)$$

Hence in the limiting case where n has its maximum value

$$C = \frac{V_1\,x}{r\,n^2}$$

so that the loss by heating in the whole conductor

$$= r\int_0^n \frac{V_1^2 x^2}{r^2\,n^4}\,d\,x,$$

or, since in the limiting case

$$V_1^2 = r\,n^2\,P$$

the loss $\quad = \frac{2}{3}\,n\,P \quad \ldots \quad \ldots \quad \ldots \quad (41)$

But the power utilised $\quad = \int_1^n V\,\frac{d\,C}{dx}\,d\,x$

which in the limiting case $= \frac{4}{3}\,n\,P; \quad \ldots \quad \ldots \quad \ldots \quad (42)$

that is, in this approximate solution, the total power taken from the line is $\frac{4}{3}\,n\,P$, where P is the power taken off per mile at the end remote from the dynamo, instead of being simply $n\,P$, as it would be if uniform amount of power, and not a uniform current, were given off per mile. Using this value given by (42), we have

for f, the ratio of the total amount of power lost to the total amount utilised,

$$\frac{\frac{2}{3} n P}{\frac{4}{3} n P} = \frac{1}{2},$$

so that e, the electrical efficiency for the longest possible line, and which must be the minimum electrical efficiency for the given values of P_1, V_1, and r, equals

$$\frac{1}{1 + \frac{1}{2}}$$

or $\frac{2}{3}$, or $66\frac{2}{3}$ per cent.

XI. Next let us consider the minimum electrical efficiency actually obtainable in distributing power with a telpher line, and the greatest length that a telpher line may have when the power, and not the current, given out per mile is the constant, and when V_1, r, and P are given.

We have

$$V_1 = V_0 \psi \left(\frac{r P x^2}{V_0^2}\right),$$

and we desire to know what real value of V_0 will make x a maximum when V_1, r, and P are given. We must therefore make $\frac{d x}{d V_0}$ equal to nought, or, writing z for $r P x^2$, we must make $\frac{d z}{d V_0}$ equal to nought. Differentiating with respect to V_0, we have

$$0 = \psi \left(\frac{z}{V_0^2}\right) + V_0 \psi' \left(\frac{z}{V_0^2}\right)\left\{ - \frac{2 z}{V_0^3} + \frac{1}{V_0^2} \frac{d z}{d V_0}\right\}$$

$$0 = \psi \left(\frac{z}{V_0^2}\right) - \psi' \left(\frac{z}{V_0^2}\right) \frac{2 z}{V_0^2} + \frac{1}{V_0} \psi' \left(\frac{z}{V_0^2}\right) \frac{d z}{d V_0}.$$

Hence, writing y for $\frac{z}{V_0^2}$, we have, putting $\frac{d z}{d V_0}$ equal to nought,

$$\psi (y) = \frac{d \psi (y)}{d y} . 2 y, \quad \ldots \quad \ldots \quad (43)$$

and we must find the value of y that makes (43) true.

From the preceding tables the value of y is most easily found by letting any two consecutive values of $\psi (y)$ and y be

called ψ_1, ψ_2, and y_1, y_2, and seeing what value of y most nearly satisfies the equation

$$2\frac{\psi_2 - \psi_1}{y_2 - y_1} - \frac{\psi_2 + \psi_1}{y_2 + y_1} = 0.$$

Using Table III., since Table VI. does not extend far enough we have for the values of y and of the expression on the left-hand side of the last expression—

y.	*Expression.*
	$2\frac{0{\cdot}1254}{0{\cdot}3300} - \frac{4{\cdot}3576}{5{\cdot}45}$ or $-\ 0{\cdot}040$
2·89	
	$2\frac{0{\cdot}1299}{0{\cdot}3500} - \frac{4{\cdot}6129}{6{\cdot}13}$ or $-\ 0{\cdot}010$
3·24	
	$2\frac{0{\cdot}1343}{0{\cdot}3700} - \frac{4{\cdot}8771}{6{\cdot}85}$ or $+\ 0{\cdot}014$
3·61	
	$2\frac{0{\cdot}1384}{0{\cdot}3900} - \frac{5{\cdot}1498}{7{\cdot}61}$ or $+\ 0{\cdot}033.$

Interpolating, we find that for y equal to 3·21 the expression is nought; hence no telpher line can have a greater value of y than 3·21, and the electrical efficiency corresponding with the value of y, and which is the least electrical efficiency of any telpher line, is 0·582, or 58·2 per cent.

The greatest possible length of any telpher line is n miles

where $$\frac{r P n^2}{V_0^2} = 3{\cdot}21$$

and $$V_1 = V_0 \psi(3{\cdot}21)$$
$$= V_0 \times 2{\cdot}36 \quad \ldots \quad \ldots \quad (44)$$

so that $$n = V_1 \sqrt{\frac{0{\cdot}5763}{r P}} \quad \ldots \quad \ldots \quad (45)$$

With a given value of V_1, r, and P, (44) enables us to calculate the limiting value of V_0, and (45) the limiting value of n, the length of the line. It will be found that for values of n slightly less than that given by (45) the efficiency is considerably greater than 58·2 per cent., and hence it is not advisable to approach the limiting condition.

Taking the same numerical example as before, let

$$V_1 = 200 \text{ volts},$$
$$r = \tfrac{1}{2} \text{ ohm},$$
$$P = 2{,}000 \text{ watts per mile};$$

then $$n = 2\sqrt{5 \cdot 763}$$
$$= 4 \cdot 8 \text{ miles};$$

whereas, from the approximate formula (38),

$$n = \sqrt{20}$$
$$= 4 \cdot 472 \text{ miles};$$

also, from (44), $V_0 = 84 \cdot 74$ volts.

XII. We will next, as an example, determine the current flowing along the line, and the P.D. at each point, when we take the total length of our line as being, not 4·8 miles, but 4·472 miles long, since, as we shall see, this small diminution of length much increases the electrical efficiency.

To find the value of V_0 we must solve the equation

$$V_1 = V_0 \psi \left(\frac{r P n^2}{V_0^2}\right)$$

$$\text{or } 200 = V_0 \psi \left(\frac{20{,}000}{V_0^2}\right).$$

Let us write $f(V_0)$ for

$$200 - V_0 \psi \left(\frac{20{,}000}{V_0}\right),$$

then we must find the value of V_0 that makes $f(V_0)$ equal to nought. By means of the tables we find that when V_0 equals 100 volts

$$f(V_0) = 200 - 100\,\psi(2)$$
$$= 10 \cdot 37;$$

when V_0 equals 130 volts,

$$f(V_0) = 200 - 130\,\psi(1 \cdot 183)$$
$$= -2 \cdot 0219;$$

when V_0 equals 125 volts,

$$f(V_0) = 200 - 125\,\psi(1 \cdot 28)$$
$$= 1 \cdot 1;$$

so that $V_0 = 126 \cdot 75$ volts

is the P.D. at the end of the line when the total length of the line is 4·472 miles.

Now $$y = \frac{r\,P\,x^2}{V_0^2}$$

∴ if for simplicity of calculation we take

$$V_0 = 126{\cdot}5 \text{ volts},$$

$$y = \tfrac{1}{16}\,x^2.$$

And $$C = 10\,\sqrt{40}\;\phi\,(y)$$
$$= 63{\cdot}25\;\phi\,(y);$$

also $$V = 126{\cdot}5\;\psi\,(y).$$

Hence, using Table VI., we are able to calculate Table VII., where C is the current in amperes flowing, and V the P.D. in volts at any point of the line (x) measured from the end remote from the engine-house.

Table VII.

x.	*y.*	*C.*	*V.*
0	0	0	126·5
0·4	0·01	6·33	127·1
0·8	0·04	12·65	129·2
1·2	0·09	18·97	132·3
1·6	0·16	25·33	137·8
2·0	0·25	31·66	142·3
2·4	0·36	36·05	149·2
2·8	0·49	42·38	156·8
3·2	0·64	46·36	165·4
3·6	0·81	51·17	175·7
4·0	1·00	55·66	185·9
4·4	1·21	60·09	197·4
4·472	1·25	60·72	199·6

From Table VI. we find that the value of e corresponding with 1·25 for the largest value of y in Table VII. is 0·738, or 73·8 per cent. Diminishing, therefore, the length of the telpher line from 4·8 to 4·472 miles increases the efficiency from 58·2 per cent. to 73·8 per cent.

The PRESIDENT: At this late hour it is impossible to go on with the third paper set down for this evening, and we must therefore defer it for a future occasion. I am sure you will all

support me when I move that our best thanks are due to Professors Ayrton and Perry for their interesting and valuable communications.

The motion was carried unanimously.

The PRESIDENT: The next meeting will take place on Thursday, March 25, 1886, when a paper will be read by Mr. Alexander Bernstein on "Electric Lighting by means of Glow Lamps of Low Resistance."

A ballot for new members then took place, at which the following candidates were elected:—

Members:

Alfred S. Bolton.	Lucien Gaulard.

Associates:

Archibald Douglass.	Edward W. Lancaster.
Guy Carey Fricker.	George A. Mason.

William Webster, Jun.

The meeting then adjourned.

The One Hundred and Fifty-fourth Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, March 25th, 1886—Professor D. E. Hughes, F.R.S., President, in the Chair.

The minutes of the previous meeting were read and approved.

The names of new candidates were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council, viz.:—

From the class of Associates to that of Members—

Lieut. R. W. Anstruther, R.E.
Frederick Adam Hamilton.
Herbert Kingsford.

Donations to the Library of the Society were announced as having been received since the last meeting from: the Institution of Civil Engineers, the Astronomer-Royal, and Mr. W. McGregor, Member, to all of whom the thanks of the meeting were unanimously voted.

The Secretary announced that he had been requested by Dr. W. H. Stone, Member, physician at St. Thomas's Hospital, to inform the members of the Society that he would be happy to see any of them at the series of Lumleian lectures to be delivered by him at the College of Physicians on the 8th, 13th, and 15th April, at 5 p.m., on "*The Electrical Conditions of the Human Body: Man as a Conductor and Electrolyte.*"

The following paper was then read:—

ELECTRIC LIGHTING BY MEANS OF LOW-RESISTANCE GLOW LAMPS.

By Alexander Bernstein, Foreign Member.

It is not uncommon in the history of technical science to find that constructions which have at one time been abandoned on account of apparently insurmountable difficulties have, after a

certain lapse of time, been readopted. The high-speed engine, the high-pressure boiler, the multiple telegraph system, were known and made long before they were generally applied, because their practical application was impossible until a certain amount of experience had been obtained by means of the low-speed steam engine, the low-pressure boiler, and the single telegraph system.

In a very similar manner the low-resistance glow lamp was known and made more than thirty years ago, but has hitherto been considered impracticable. In the meantime the glow lamp of high resistance has made its way, and has met with considerable success. Now to-night I desire to revive the older type of lamps in a new form produced by means of our present experience, and to show at the same time the way in which these lamps may be made to answer the purpose of electric lighting.

As we have been so often told that the lamp of low resistance is neither practical nor economical, I must suppose that most electricians are somewhat prejudiced against it. But prejudices are detrimental to the development of truth, and I must therefore request you to take as impartial a view as possible of the case which I shall lay before you to-night.

High or low resistance of glow lamps is not merely a question of construction of the lamp itself; it is a question of principle which determines the whole system of lighting. The requirements of the dynamo, the sizes of the conductor, and the whole system of arranging the circuit, are entirely dependent upon the lamp which we select. It is therefore not sufficient to compare different types of lamps in regard to their qualities as lamps; it is quite as essential to consider how the use of these lamps answers the practical purpose of electric lighting. I shall therefore divide my paper into two parts—the first dealing with the lamp itself, the second with the manner of its application.

In speaking of glow lamps, and considering their merits, I shall only take such lamps into consideration in which carbon is brought to a state of incandescence, and emits light by reason of its elevated temperature. Although other substances may be used, experience has shown so far that none of them offer the advantages which are secured by the use of carbon, viz., the

possibility of applying a very high degree of temperature. This is very essential, because the highest temperature implies the greatest efficiency; and efficiency, together with durability, are the two qualities which principally determine the merit of an incandescent lamp.

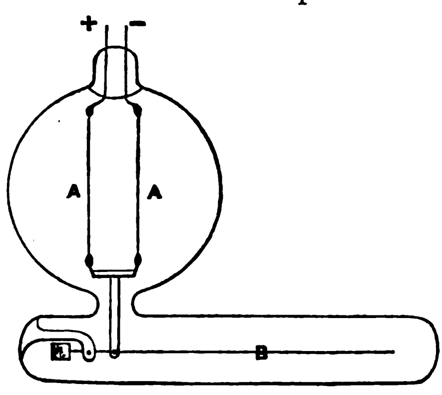
Before proceeding any further, allow me briefly to enumerate the principal parts which constitute an incandescent lamp. These are only four—the glass bulb, the conducting wires (which alway consist of platinum as far as they are surrounded by glass), the light-giving carbon, and the connection between the carbon and the wires (generally called the mounts). The simple construction of such a lamp does certainly not indicate that its manufacture is beset with so many difficulties. In order to settle our terminology, I shall further mention that the reciprocal of the number of watts required for every C.P. of light emitted will be called the "strain;" so that the strain is small if the number of watts per candle is comparatively large.

The light which is emitted by incandescent carbon depends only upon its temperature and the amount of its radiating surface; but the energy which is required to maintain this light would be determined—irrespective of the losses which may occur in the lamp, and under the supposition that the state of vacuum and the exterior temperature remain unaltered—by those same two magnitudes alone, if the radiating power of all carbon were alike. It seems to me that this last is not the case. From certain analogies, well known in physical science, we may conclude that a black, sooty carbon will radiate more heat than a carbon of a dense grayish surface raised to the same temperature, and consequently the former will require a larger supply of electric energy to maintain it at the same temperature than the latter. This fact seems entirely borne out by observations made on glow lamps.

Let us now consider the peculiarities of a glow lamp of high resistance, say of 100 volts and 0·6 ampère. I select this lamp because it seems that this is approximately the highest resistance lamp which can be practically applied at the present time. At least, I can see no reason why the complicated expedient of a

multiple-wire system should be used, if electric lamps can be made reliable when working at a much higher difference of potential and with a corresponding smaller current. As the lamp is only to take 0·6 ampère, the filament must be exceedingly fine in order to become sufficiently heated by this current, and moreover, the filament must be of sufficient length to obtain the necessary amount of light-giving surface. As soon as the current is passed through the filament, the latter is raised to a certain state of incandescence; and we shall therefore have to deal first of all with the effect which heat alone seems to have upon the carbon.

Heat has a general tendency to expand all substances; and as it was interesting to know how far carbon is subject to the same law, I have investigated this question by means of a lamp of the following construction:—Two straight filaments are connected by means of a cross piece of platinum in the form of a T, which acts on a lever so arranged as to indicate ten times the elongation of the filaments when these are heated. The annexed sketch, in which A A are the filaments, and B the indicating lever, shows the arrangement which was adopted. The experiment indicated that when the carbons were exposed to a strain of 3 watts



per candle, the elongation of the filaments amounted to one 120th part of their length. It was further noticed that the rate of expansion was not constant, but increased with the temperature, although at the highest temperatures obtained the coefficient of expansion seemed to decrease again.

The fact that the carbon expands and contracts with every change of temperature explains why lamps with slender filaments are destroyed more quickly when subjected to varying currents than when they are fed by a constant and uniform current, such as that supplied from batteries.

When we look at a heated filament, we notice sometimes that one small spot is brighter than the rest of the filament. This is an indication of a flaw which will sooner or later produce the disintegration of the carbon at this particular spot. These flaws are, for the most part, so minute that they cannot be perceived in the filament when cold, and only gradually show themselves when the lamp is being used. This is one of the causes which produces premature destruction of the lamp. The finer the filament the greater the danger of a flaw.

It has lately been supposed by some writers on the subject that the life of a glow lamp is in direct proportion to the diameter of the filament. Such suppositions, which are mostly made for the sake of obtaining mathematical formulæ, are far too sweeping; and all we are entitled to say is that, *cœteris paribus*, the lamp with a thick filament promises greater durability than the one with a thin filament.

We have before observed that heat produces expansion of the carbon, and from this we may infer that if the heat is sufficiently high, evaporation or disintegration of the carbon would be the result. Such is the case if the carbon is of a soft quality and raised to a very high degree of temperature; but we are fortunately in a position to produce a carbon of such dense and hard structure that there seems to be no perceptible disintegration at the temperature usually employed in incandescent lamps. If we, nevertheless, observe in high-resistance lamps—even if worked at a strain of no more than 4 to 5 watts per candle, and a corresponding low temperature—that the carbon filaments are disintegrated, that the resistance of the lamps consequently increases, and that the glass bulbs begin to blacken, we are led to suppose that other forces must be at work which produce the destruction of the lamp. These forces are of an electrical nature, and their existence is easily explained if we consider that an electric glow lamp is at the same time a vacuum tube.

In the high-resistance lamp we have considered before, there is a difference of potential of 100 volts between the two terminals of this vacuum tube. The fact very soon makes itself apparent in the lamp. If the temperature is sufficiently high, the negative side of the carbon assumes a dark, sooty appearance, and a deposit of black loose carbon is formed on the positive platinum and mount. This action of throwing off particles of carbon from the negative side towards the positive has been the subject of a very interesting paper communicated to the Royal Society by Mr. Preece. The peculiar behaviour of high-resistance filaments is evidently the effect of a combined action of heat and electricity. The heat lessens the attraction of the particles for each other, and the electric forces produce motion. The result is the gradual deterioration and ultimate destruction of the carbon.

It has often been noticed that a blue flame makes its appearance upon the positive platinum when the carbon is raised to a high state of incandescence. As no explanation of the production of this blue flame has as yet been given, I beg leave to insert here a few words respecting the most probable cause of it.

All platinum, when cold, occludes a large quantity of oxygen, which is given off again when the platinum becomes heated. The black, sooty deposit of carbon on the positive platinum is just in a condition to combine readily with the oxygen, and both together form the blue flame. While the lamp is on the vacuum pump this flame may often be seen to travel up and down the platinum wire, always appearing where occluded oxygen is set free. If the pumping continues without the current being increased, the quantity of free oxygen is soon consumed, and the blue flame disappears, but reappears again if the temperature of the platinum is increased by increasing the current. Just in the same manner finished lamps will, under all normal conditions, show no blue flame, but will do so if an excessive current is passed through the lamp. In this case a blue flame is sometimes seen on the negative platinum as well. This occurs because particles of carbon find their way to the negative platinum and are oxidised there in the same manner. As the spectrum of the blue

flame has been observed by Messrs. Liveing and Dewar to be that of carbonic oxide, it seems so much the more probable that the explanation here given is correct.

We have now to notice another effect of the vacuum tube. When lamps are made for very high difference of potential and corresponding small current, there seems to be a very strong tendency of the current to leap across from one terminal to another, thereby short-circuiting the lamp, destroying the filament, and fusing the platinum wires. This tendency is very strong when the current is turned on suddenly, as the carbon, being cold, then offers the highest resistance to the passage of the current.

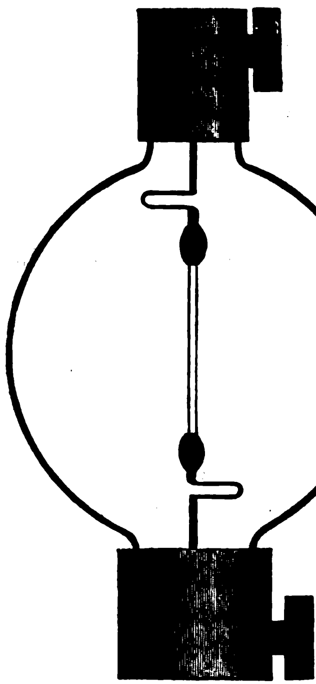
One of the conditions which it is desirable to observe in respect to a practicable lamp is that a certain excess of current such as is liable to occur in installations must not be able to destroy the lamp; and in this respect it is certain that the lamp with a thick filament is far superior to the lamp with a thin filament.

Turning to another point of practical importance, we notice that lamps with fine filaments are exceedingly subject to flickering as soon as the strength of the current varies but slightly. Variations of this kind may have their cause in irregular motive power, in slipping of a belt, or in a dynamo which is not perfectly balanced either mechanically or electrically. Such flickering will be noticed in a great many installations with small-current lamps, and is exceedingly disagreeable to the eye. Now, with a large hollow carbon used in the lamp which I shall presently describe, the interior is always at a higher temperature than the exterior, and serves as a reservoir of heat which allows for certain variations in the current, without any effect on the eyes as regards the light.

How are we, then, to obviate these difficulties appearing in the lamp? If the thin filament does not promise much durability, and is disadvantageous in other points mentioned,—if the high difference of potential proves to be a factor in the destruction of the lamp,—we must employ thick filaments and a small difference of potential; or, in other words, we must produce a low-resistance lamp.

I think I have sufficiently shown you the right of existence of a low-resistance glow lamp, and I shall now proceed by describing

the lamp which is before you, the form of which seems to be one of the best of all the varieties of low-resistance lamps which I have made since 1882.



The lamp which is shown in the above figure consists of a glass bulb of oval shape, into the opposite ends of which the platinum wires are sealed. In this manner the glass is placed symmetrically round each wire, and is therefore less liable to crack when heated. The carbon has the form of a straight tube mounted upon short pieces of stout platinum, which are joined to the platinum wires passing through the glass by means of flat thin copper strips, bent upon themselves so as to form springs at right angles to the direction of the carbon. In this way all parts of the lamp can expand and contract without subjecting the carbon to any injurious strain. A cap of insulating material at each end of the glass bulb provides for proper connection with the conducting wires, which may be made to support the lamp; and this connection is made in such a manner as to

prevent accidental contact of the manipulator with any part carrying a current.

The success of these lamps depends on the satisfactory construction of every one of its details in an almost equal degree. The quality of the carbon, the way in which the same is mounted, the manner of surrounding the platinum wires with the proper kind of glass, the avoidance of any mechanical strain, and the proper proportion of every part of the lamp, are all the results of tedious experiments, which were necessary in order to produce a satisfactory lamp. The electrical dimensions of the lamp are as follow :—It requires a current of 9·75 ampères, thereby showing a difference of potential of 7 volts, and a hot resistance of about 0·7 ohm.

When speaking of the high-resistance lamp, I have mentioned that there seems to be a limit to the difference of potential which we can apply in each bulb. As regards the low-resistance lamp, there is a limit to the strength of the current of which we can avail ourselves. The difficulty rests with the wires, which have to be sealed air-tight into the glass, as it is far easier to seal in thin than thick wires carrying a large current.

Before concluding this first part of my paper, I shall have to mention one of the drawbacks of the low-resistance lamps, to which Professor Forbes has called attention in his excellent lectures on the distribution of electricity, viz., the loss of heat in the conductors inside the lamp. I quite agree with Professor Forbes that in older types of lamps the loss was very considerable, and a serious question; but in the lamps which I made some years ago this loss amounted to only one-tenth part of the energy consumed. I am happy to inform you that in the lamp before you this loss has been reduced to one-twentieth part of the energy required in the lamp.

I shall now turn to the second part of my paper, and I shall consider it best to attack at once the most difficult problem which can present itself, viz., the supply of a large number of lamps from one central station, with the condition that all the lamps can be used entirely independent of each other, and with the further condition that the expenditure of mechanical energy shall always

be proportioned, or, at all events, approximately proportioned, to the number of lights in use. Our imaginary plant is to be arranged for 6,000 lamps, requiring 9·75 ampères, and upon the average 6 volts each. Let us first look into the central station and consider its requirements. We shall settle upon the use of a dynamo which with a current of 10 ampères is capable of producing an E.M.F. of 2,000 volts—a kind of dynamo which was first applied by Mr. Brush, and which is already extensively used for arc lighting, or for a combination of arc lights with groups of glow lamps, several of the latter being always arranged in parallel. But the lamps of which I spoke at greater length in the first part of my paper are made for the passage of the whole current, and will therefore be arranged in series, one being placed in the line after the other. In this case there will be more than 300 lamps on each line; let us say 300. We shall therefore require 20 such dynamos, and one or two spare machines in case of repairs. These 20 dynamos may be driven from shafting, or each by a separate steam engine. There are 20 separate lines proceeding from the central station, and as the main condition of our system is that the current on every line must always be kept constant, we must provide for the regulation of each dynamo in such a manner that the E.M.F. always corresponds to the number of lamps which are in use. This regulation can be effected by automatic devices, or may be done by hand in adjusting the magnetic field or the speed of the dynamo. An ampère-meter which is placed in every circuit will indicate whether this condition is fulfilled, and a voltmeter connected with the terminals of each circuit will inform us how many lamps are used on each line at any time. A registering voltmeter placed in the same manner would be another useful addition. The central station, furthermore, contains a switch-board, which allows any one of the circuits to be connected with any one of the dynamos. If we presume that the station is to supply current day and night, it would certainly be absurd to run all the dynamos constantly at those times, when only a small number of lights are required. At daytime, then, I should propose to loop several circuits together, and if the total number of lamps is sufficiently low, all the 20 circuits

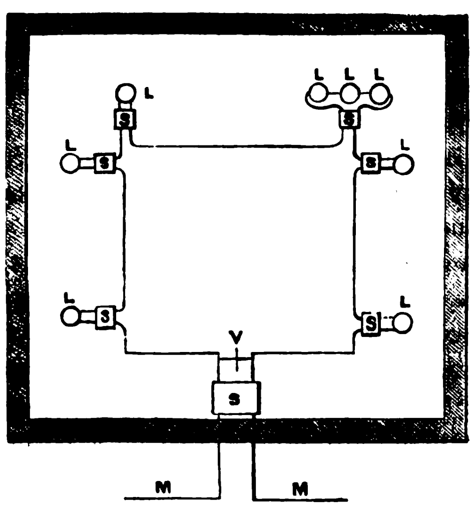
might be looped in a single one, so that only one dynamo need be kept running. By means of an auxiliary line of lamps in the central station, dynamos and circuit may be switched in and out without any sudden change in the conditions of either. The system of working would then be that in the afternoon one dynamo after the other is switched into its respective circuit, the requirements of which can always be ascertained on the volt-meter of this circuit. If the consumption of light decreases, the dynamos are gradually switched out again. By the addition of an arrangement for observing and measuring the state of insulation of every line, the outfit of the central station might be considered complete. I have not mentioned any apparatus in connection with the central station which could not be easily constructed with the means at our disposal at the present time.

We now leave the central station, and turn our attention to the conductors. These are 20 pairs of copper wires of small size, say No. 6, well insulated. Experience has shown, so far, that there seems to be no great difficulty in insulating a wire if the tension of the current is not more than 2,000 volts. If we suppose that the central station is in Pimlico, on the banks of the Thames, a few wires may be laid in the direction of Victoria Station, a few more may reach the Houses of Parliament, some may be laid in the direction of South Kensington Museum, and some others may be used for lighting private houses—in each of which I shall suppose that, upon an average, 20 lights are used at the same time. In this case 15 houses are passed by the same conductor, which supplies current for 300 lamps. All these lights can be turned on or off at will, quite independent of each other, because we have provided in the central station that each dynamo is regulated in such a way as always to produce the same strength of current, no matter whether there are 300 lamps alight in each conductor, or only 10.

Let us now compare this system with the only other system in which glow lamps are arranged quite independent of each other, leaving out the consideration of secondary generators. In the parallel system the central station must be in the centre of the district to be lighted, which is often very objectionable, and

sometimes impossible. In the series system the station may be far out of the way. In the parallel system we are restricted to the use of a 100-volt lamp, as we have seen before, and, in consequence, the radius of the district to be lighted must be kept very small, or the expenditure for conductors would be prohibitive. In the series system the expense for conductors is comparatively small, and we may reach any distance. The parallel system requires that a fixed difference of potential should be maintained in all the conductors under varying strength of current—a condition with which it is even theoretically impossible to comply, and which entails enormous practical difficulties. In the series system we have to maintain a constant current under varying resistances—a condition which can be easily fulfilled. When the parallel system was first developed, the prevailing idea appears to have been to make electric lighting from central stations similar to gas lighting. But the conditions under which electrical energy in its active form is best transmitted are so different from those requisite for the transmission of the potential energy of gas, that the desire to imitate the gas system has proved rather a disadvantage.

We now arrive at the last, and perhaps the most difficult, part of the whole installation, viz., the outfit of the place which is to be provided with lamps. For the sake of simplicity, I will suppose

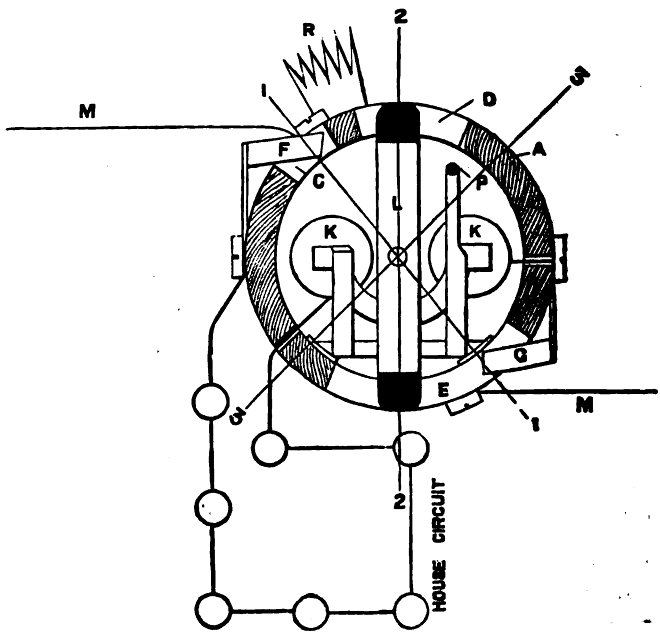


the place to consist of one single room, as shown in the sketch. In this sketch the small circles ○, marked L, represent lamps; the squares □, marked S, represent switches (which will be presently described); and the cross +, marked V, is to indicate a registering voltmeter. The street main, M, enters the house at the main switch, drawn larger than the others; it continues from switch to switch, and returns to the main switch before leaving the house. We have supposed the street mains to be composed of No. 6 copper wire, but the house mains may be made equal in section to No. 10 wire, in order to be more flexible. The lamps are always connected to their respective switches.

From what has been said before, it is quite evident that the first and essential condition of such a system must be that the circuit is never to be opened, whatever may happen. As we are always dealing with a closed circuit, it will prevent misunderstanding if we give a different designation to the two ways in which the circuit can be completed; and I shall therefore call the circuit "short-closed" if the current goes directly through the switch-lever, and "long-closed" if the current is led through the lamps or other electric devices, such as motors, which are to be acted upon. The fact that the circuit is never to be opened reduces one great difficulty in the switch required in the paralled system, viz., the liability to produce an arc.

The main house switch, to which I shall now invite your attention, serves the purpose of either short-closing the street circuit, so that no current can pass into the house, or of long-closing the same, thus including the house circuit into the main circuit. In the first case I have not considered it sufficient merely to prevent the current from entering into the house; I have thought it advisable to disconnect the house circuit entirely from the street circuit at the same operation, so that any alteration of the circuit may be made inside the house without the possibility of a branch current being established, even if the street circuit should be of defective insulation. But this switch is also made to answer another purpose. Supposing that the street circuit, which has been short-closed, is now to be long-closed, but that by some accident or another a break of the continuity of the line has

occurred in the meantime inside the house: if now the switch-lever were to be moved with the intention of allowing the current to enter the house, the result would be the formation of a long arc, and eventually the whole current would be interrupted. The manner in which this has been rendered impossible can be best explained by reference to the annexed sketch, in which A is the switch-box, made of insulating material, and L the switch-lever, made of conducting material. C, D, and E are three pieces of metal let into the upper edge of the circular box. The lever L may occupy three positions, marked 1, 2, and 3. In position 1, C is connected with E, and as C is one terminal of the main circuit and E the other, this circuit is now short-closed. But if the lever L is in position 1, it lifts two flat springs of metal, F and G, which are the terminals of the house circuit, from their respective seats on the metal pieces C and E. The lever L carries on its upper side two pieces of insulating material, on which the two springs F and G now come to rest, and consequently the house circuit is out of all electrical connection with the main circuit.



If it were now intended to allow the current to pass into the house circuit, the lever L would have to be turned from position 1 to position 3; but when the lever passes over the intermediate position, 2, it first connects the metal piece D with E. But the metal piece D is permanently connected with C by means of the resistance, R, and the main current will therefore be divided in two parts—one, the greater portion, passing through R and L to E; the other, the smaller portion, passing through the house circuit in case the same is complete. This house circuit includes the electro-magnet, K, which is situated inside the switch, and the armature of this electro-magnet carries a pin, P, which is in such a position that it is below the plane of the motion of the lever L if the armature be attracted, but hinders this motion if the armature be not attracted. In case, then, that the house circuit is complete, there will be no impediment to the further motion of the lever L from position 2. It will therefore reach position 3, where it rests upon pieces of insulating material, and the whole current now passes through the house circuit. But if the house circuit had not been completed, the motion of the lever would have been arrested by means of the pin P, and a break in the circuit is in this way made a matter of impossibility.

I shall pass at once to the lamp switch, because it is practically a mere repetition of the main switch on a smaller scale. But the lamp switch contains an additional arrangement, which would be a useful adjunct to the main switch as well, viz., the automatic cut-out. This is intended to act if the lamp should fail during the passage of the current, in which case the break of the circuit is prevented by short-closing it around the lamp. The arrangements which I have used to provide for this eventuality are of two kinds, and may be shortly described without reference to any drawing. Both are based on the principle that if the resistance of the lamp increases—which always occurs in lamps placed in series when the carbon gives out and an arc is formed—then a current in a shunt around the lamp will increase. In one of these arrangements this increased current is made to act upon the armature of an electro-magnet, which armature releases a spring for the purpose of making a direct secure contact between

two places of the circuit in which the lamp is situated, and a short circuit is thereby formed round the lamp. In the other arrangement a fusible wire is placed in the shunt, and a lever is arranged in such a way as to be acted upon in one direction by the wire, and in the other by a strong spring. If the wire fuses, the spring presses the lever against contact pieces, which serve the same purpose as specified above. In neither case can the circuit, which is now short-closed, be made to include the lamp again until the cut-out lever has been moved into its former position by hand. The combination between the switch and the cut-out lever is such that the switch-lever has to be placed into position 1 before the cut-out lever can be operated upon by hand. The reason for the adoption of this last arrangement will become evident by a consideration of the peculiarities of the switch which I have mentioned before. I believe that in this way I have provided for the prevention of a break in the circuit which may occur from any eventuality.

I need not dwell on the construction of the lamp-holder, the only part of the outfit which has not yet been mentioned. It may be made in different ways, but one principal idea has been adhered to in its design, as well as in that of all other details which constitute the outfit of a house: there is no part conveying a current which is not perfectly insulated, or which is in any way exposed so as to offer the possibility of any person coming into contact with it. This is hardly possible in arc light circuits, but may easily be done where only glow lamps are used.

And this brings me to the last question which I shall have to consider, namely, the question of safety. Here again I shall have to note one very great advantage of the series system over the parallel system, and this is the impossibility of a wire becoming overheated. Every experienced electrician knows as a fact that short circuits in the parallel system have often led to detrimental results in spite of safety fuses; and a system in which such a danger does not exist, and which consequently does not require any provisions against it, has certainly much to recommend it. Especially in such cases in which the danger of fire must be most dreaded—in ship lighting—I believe that this advantage of the series system will be very greatly appreciated.

I now come to the objection generally raised against the use of high-tension currents. If an inventor were to appear to-day saying he wanted to introduce into our houses a substance which, when properly used, was intended to give light, but which in itself was a poison, and produced poisons when used as a light, and of which it was further known that it was always ready to form an explosive agent when mixed with atmospheric air, I believe that the critical spirit of our time would raise an outcry against the introduction of such a dangerous substance, and against the use of the public streets for its conveyance. But this substance—of which we know that it is quite harmless as long as it is retained within metal tubes—is now actually carried into all our houses, and we are so familiar with its peculiarities that no one feels any nervousness nowadays in the neighbourhood of a gas chandelier.

In conveying a high-tension current into a house we are in a far more favourable position than if dealing with gas, because the probability of an accident is far more remote. Three conditions must be fulfilled before any person can be injured by an electric current. First, there must be a certain amount of leakage on the line; secondly, the person must be in contact with a bare conductor; and, thirdly, the person must at the same time be in contact with the ground.

In the system of central lighting which I have laid before you it is easy enough to constantly ascertain the condition of the line, and far easier to locate a fault than in a complicated system of branch wires. It is, further, easy to construct all parts of the system inside a house in such a manner that contact with a bare conductor is impossible; and, moreover, a person standing on a carpet and a dry wooden floor is exceedingly well insulated. The tension which we can use with safety depends simply upon our means of insulation. If you will recall the precautions which have been taken in the construction of the switches by entirely disconnecting parts of the circuit from the main circuit, when lamps have to be replaced or alterations to be made in the circuit, then I think you will agree with me that the probability of an accident is exceedingly remote; and this system of lighting

appears to offer more safety than any other method of artificial lighting at present in use.

And now, in conclusion, I should like to say that in a short paper like this which I have had the honour of reading to you, I found it impossible to enter more fully into details than I have done, and I have therefore restricted myself to the explanation of those details and the discussion of those questions which appear to me of prominent importance. I hope that by my humble efforts I may have accomplished the object of my labours, namely, the further extension of the field of electric lighting.

A Bernstein lamp, lighted by a current from an E. P. S. Co.'s battery, was on the table.

Sir David Salomons: Mr. Bernstein has omitted to say what is the candle-power of the lamp exhibited.

Mr. Bernstein: The lamp now at work is a full 20-candle-power lamp.

The President: We have listened to a most interesting paper this evening, and Mr. Bernstein has brought out some new facts, upon which I feel sure there are many present who can give us some information. Perhaps Sir David Salomons will favour us with his remarks.

Sir D. Salomons: I would rather that the discussion were opened by other gentlemen, so that I might hear what they had to say first, as no doubt they will be better able to raise questions on the paper than myself.

On the invitation of the President,

Mr. Preece. Mr. W. H. Preece said: Mr. President,—The paper that has just been read shows that Mr. Bernstein has devoted close and intense thought to this most valuable subject—valuable for the reasons which he himself gave us at the close of his paper, where in a rather poetical style he brought before us the fact that so few of us realise, that where gas is burned we are introducing into our houses poison. Now, as one who has experienced the advantage of having his house lighted by electricity, I can say this, that no one knows what it is to live until he exists under the influence of the electric light. It removes all those feelings

of depression and discomfort that are so often found in the shape of headaches in the morning. I am quite certain that, if with the aid of Mr. Bernstein's plans, as developed by him this evening, we can introduce into the households of our neighbours the comforts I have experienced, we shall as a society do more good than all the sanitary institutions in the world. Mr. Bernstein did one dangerous thing: he tried to impress upon our minds a new term. Now there are other persons who have at different times introduced into electrical language new terms, and have been sat upon. I do not mind, having been sat upon myself, sitting a little bit upon Mr. Bernstein; and while I am perfectly ready to admit that he is quite justified in speaking of the number of watts per candle as something that deserves a new term, I am bound to object to the introduction of the word "strain" as that term. It is always inconvenient to introduce any word that has an ambiguous meaning. We know from experience in electricity that there is nothing that causes us more trouble than the words "tension" and "intensity," and it is simply because these two words are each applied to different meanings and to different conditions. Mr. Preece.

The word "strain" is one that is fixed in our minds as something associated with mechanics and the strength of materials. I wish Mr. Bernstein had gone to Greek or Latin, Hindoo or any other language, and have introduced a term which would have conveyed the idea he wanted to express, and that idea only. I do not like to criticise a paper that has been so very well received. There is a great deal in Mr. Bernstein's paper with which I most fully agree. He has placed before us in a very clear way the relation that exists between temperature and the radiating power of incandescent carbon; and the fact that the light-giving power of carbon is a function of the temperature, is one that out to be thoroughly borne in mind by those who are working at incandescent lamps. He told us first that fine filaments had a *short* life, because they required a high temperature; whereas towards the end of the paper he told us that glow lamps of low resistance had a *long* life, because they had a high temperature. Well, the two reasons were identically the same, but I can clearly

Mr. Preece. understand why there should be this great apparent difference of conditions. Mr. Bernstein was kind enough to make for me some beautiful little lamps with a very fine filament, that required a very high temperature and gave a most beautiful and exquisite light; but they broke rather sooner than I wished. I contend that as long as we are fixed to carbon filaments of high resistance, so long are we dependent upon the price of the lamp supplied to us, and upon its life; and we want to have carbon filaments supplied to us so cheaply that we can afford to burn them at a very high efficiency (at a very high strain, as Mr. Bernstein would say), without caring whether they last 24 hours or 240 hours. People often say that they have a lamp which has a carbon of high resistance which has lasted for 5,000 hours; but they all forget that when a lamp has burned for 5,000 hours it has wasted its value over and over again in power expended. I want to have a lamp that will last from about 100 to 200 hours, and be so cheap that it will pay me to renew the lamp every 100 hours, rather than pay so dearly, as we do now, for a lamp that lasts 1,000 hours.

There is nobody who has worked on the parallel system who is not aware of the inconvenience and danger that arises from short-circuiting. When a short circuit is made, it is never known what is going to happen: it may be that the cut-out has acted promptly, and then it is all right; but it may be that the cut-out has not acted promptly, and has proved to be not a cut-out at all, and then where are you? A short circuit may happen between the wires, the insulating material may be set on fire, and the house burnt; and though I have been one of those who have, perhaps, had more than most people, to do in regard to the safety of electric lighting and its freedom from fire, I have come to the conclusion that there are just as many dangers in electricity when applied to domestic illumination as to anything else, if carelessness and ignorance are shown in the way of fitting up the premises. Electric lighting itself can be made absolutely secure, if it is known how to do it, and the dangers are due to the absence of that particular knowledge which enables us to see at once when all is safe and when all is not safe. To my mind, in Mr.

Bernstein's system the principal merit is its safety from short-circuiting. It is quite true that the main may break down, and two or three hundred lamps be put out all at once, but Mr. Bernstein has not told us what would happen then: perhaps he will tell us in his reply. Mr. Preece.

There may be one or two other questions of moment that may be asked in the course of the discussion. I simply desire to say that I very much admire the ability with which this paper has been brought before us, the clearness with which it has been written, and also the evidence that it has given to us of the deep thought that Mr. Bernstein has brought to bear on the question that interests us at the present moment, perhaps more than any other.

Mr. F. L. RAWSON: I am afraid that, being asked to speak so soon, I have only a few remarks to make. It is a very unfortunate circumstance, and one that personally I regret very much, that makers of incandescent lamps have to rely upon secrecy in their manufactures. At the present time we have to keep hidden, not only what we are doing, but also our knowledge of the subject. There are several points with reference to this paper that I should otherwise have liked to touch upon. Mr. Rawson.

I am sure we must all thank Mr. Bernstein for introducing this system to us, for it is easy enough for any one to work at and improve anything with which he is already familiar, and which everybody else is at work upon, but it is exceedingly difficult to take up a comparatively new system and work it out: for this, really Mr. Bernstein deserves all our thanks. I am sure no one could be more thankful to Mr. Bernstein than I am myself for giving us an insight into a new method of distribution, and letting us know what has been done in this direction up to the present time. I would like to ask a question on a point which, with his system, would occur very often, viz., whether there would not be a difficulty found in making joints when a lamp requires to be inserted in a new position: on such occasions there will be danger. There are many instances where fresh lamps are required to be inserted whilst the current is passing. I have a case in mind where we would have to make a joint or so per day in order

Mr. Rawson. to insert additional lamps, the lamps running night and day. Of course the difficulty can be got over, but there is a certain amount of danger in the Bernstein system from the high potential, which will hinder its adoption certainly until we are more familiarised with the present systems of low potential. I would point out that, in talking of the various means of distribution, Mr. Bernstein made no allusion to the use of secondary batteries. I mention the matter because many people, on reading his paper, would think that accumulators were not considered sufficiently advanced to be used as a means of distribution. I do not say that as a system it is advisable, but it should be mentioned. If Mr. Bernstein could and would tell us, I should like to ask him how he gets over the difficulty of keeping the mounts cool, and of the generation of gas at the mount, which of course is one of the most serious difficulties, and one which I am sure he must have found very noticeable. I would also ask whether he finds much alteration in the resistance of the lamp after it has been run.

If Mr. Preece would excuse my criticising his remarks made this evening, in connection with those he made last night at the Society of Arts, where I hoped that one would have had an opportunity of making some remarks on the interesting subject dealt with, I would like to refer to them.

Mr. Preece mentions the difficulty of short circuits. He says that he does not believe in the method of putting safety junctions to each lamp, but prefers a safety junction to each room or group of lights. The electrical engineers present know that the way we plan out the position of safety junctions or automatic cut-outs is to place a large one at the commencement of the main leads, and smaller junctions at points where the smaller wires which branch off may be unduly heated by the passage of an abnormal current, without causing the large safety junction to act. Some people use wire of No. 20 B.W.G., or even smaller, for the single lamps: in this case, planning out the safety junctions as above, a junction would nearly always be necessary for each lamp. If a No. 18 wire is used for single lamps, this will carry a large current without getting unduly heated, and it

would perhaps be unnecessary to put in a safety junction Mr. Rawson. between the lamps and the junction which controls the room or group of lights. But it is better in this case to put in a small fuse to each lamp, for if this is not done a short circuit may be made by a careless servant, and all the lights dependent on the one large fuse would go out, possibly a considerable time elapsing before the short circuit is localised and the fuse replaced. In electric light installations we have to be careful to place the safety junctions in well-recognised and accessible places. Mr. Preece may find it very inconvenient if he has a short circuit somewhere putting out the whole of the lights in one branch. If smaller junctions were added, only one lamp would in this case be put out, and probably trouble and inconvenience would be avoided.

In the early part of Mr. Bernstein's paper he mentions the deposit of black loose carbon on the platinum and mount, and speaks of it as an objection against lamps of high electro-motive force; he also touches upon the question of lamps of high E.M.F. short-circuiting inside. I do not know that he would have found much difficulty if the lamps he experimented upon had been first-class lamps with a high vacuum. Mr. Bernstein's calculations make his lamp seem efficient, but I am afraid that the temperature of the one running is so high that the life of the lamp would not be so long as it ought to be. Taking 20 °/₀ as the loss in the heating of the leading-in wires——

Mr. BERNSTEIN: One-twentieth.

Mr. F. L. RAWSON: I beg pardon—one-twentieth as the loss—we find that the filament and mount in his 20-C.P. lamp require 65 watts, which is véry high for such a kind of lamp, more especially if the apparent quality of the filament be noticed, and the loss of heat at the mounts be allowed for. I am afraid I have not closely examined his last lamps, and perhaps Mr. Bernstein has recently made improvements, but I think the earlier form did not possess a carbon of high emissivity, if I may use the expression. As to short circuits, I am inclined to think that the difficulty arising from this would lessen a good deal as people become more acquainted with electric lighting. But danger may

Mr. Rawson. arise from leakage due to bad work, from both bad insulation and careless laying of the wires. Accidents would arise if wires were broken or cut, and there are other dangers which it will always be difficult to guard against, such as short circuits from damp. We have often run wires in places which at the time were perfectly dry and appeared suitable, but afterwards something has happened—a cistern bursts and the place is soaked through, or perhaps lime or other material damages the insulation. In all cases of this sort Mr. Bernstein would have very great difficulty from his high potential.

Of course, I am only calling attention to accidents that may occur, but mistakes, even with the most careful work, cannot be entirely guarded against, and, when they do occur, would certainly be dangerous in a system of this kind.

Mr. Crompton. Mr. R. E. CROMPTON: In the year 1881, Mr. Swan showed me a scheme of house-to-house lighting, worked out on much the same plan as has been laid before you this evening by Mr. Bernstein. I then advised him that it would be difficult and complicated in the working out, as at that time it was not easy to get the various small cut-outs and switches, which this system entails, manufactured cheaply and in a trustworthy manner. Further than this, at that time the lamps were more liable to fail than they are at present, and this increased the difficulty of putting them in series. It is quite possible, now that the times have changed, lamps have improved, and the special apparatus required is more easily manufactured, that Mr. Bernstein may be able to work his series system successfully.

I have studied the subject myself, but have never been able to solve the problem of series lighting in a complete and satisfactory manner. The first difficulty that presents itself is that of satisfactory insulation of the wires. The dangers presented by a double earth on a circuit comprising, say, 30 houses in series, will be considerable. A nail driven in by a careless plumber or carpenter would affect the whole group of houses, so that if any person in any house of the same group standing on a damp floor should touch any exposed portion of the electric light circuit, he would get the whole of the enormous E.M.F. through his body,

which might kill or certainly seriously injure him. The Board of Trade regulations, although they suppose that certain mains might be charged with current of very high E.M.F., made special provision that these mains should be completely detached from the houses at the time the electric light was in use in those houses, and in this manner the dangers from earth leakages would be minimised. Mr. Crompton.

I think that the double mount required by Mr. Bernstein's new form of lamp is a disadvantage as compared with the simple form of mount required when the terminals are near together at one end of the lamp. The double mount would be an obvious source of difficulty when the lamps are fixed to pendants, or, in fact, at any time when they are suspended overhead, which in my own opinion is the most useful position in which the electric light can be used, at all events in private houses. I must differ from Mr. Bernstein in the question of lamp efficiency. I have never been able to find, when comparing the life of the lamps made by one maker, that those of low resistance have any appreciable advantage over those of high resistance. The two classes of lamps most frequently used by my firm are 55 v. and 110 v. We also use a few of 80 v. for ship lighting and for some detached installations. I have never found that the 55v. lamps show any mark of superiority over the 80, or the 80 over the 110; in fact, the life and efficiency of all three classes of lamps appear to be very much the same. I have had lamps of all three classes last, without being perceptibly blackened, up to 2,000 hours.

Mr. Preece a few nights ago, at the Society of Arts, complained that lamps lasted too long—that is to say, he only got a few hundred hours of lighting at full efficiency, and after that the lamp lasted a very long time in a dull condition, giving a yellow light. In my experience this dull condition is rarely reached with the present make of Swan lamps before they have burnt 1,500 hours, and, as I have said above, in many cases not before 2,000. It is an absolute necessity of Mr. Bernstein's system that the current should be kept constant. Mr. Willans and myself have been working at this problem for some time past, for some large plant that we have been making for charging accumulators

Mr. Crompton.

in series, and we find that although theoretically it would seem just as easy to obtain a constant current by means of electrically governing the speed of the engines, as to obtain constant difference of potential between parallel conductors, yet practically the latter is the far easier problem of the two. It is not easy to explain the cause of this difficulty, but it does exist at the present moment, although I hope that we shall eventually succeed in governing equally as well for constant current as for difference of potential; but I am not aware of any appliances in use which would so govern the current of a circuit that, if out of 300 lamps arranged in series 40 or 50 were switched out at once, the remainder would remain perfectly still and without any undesirable flicker at such times. I notice that Mr. Bernstein talks about occluded oxygen. I thought that platinum only occluded hydrogen, and not oxygen.

I have some doubt whether Mr. Bernstein's explanation of the cause of the blue flame which appears at one or other extremity of the carbon loop is a correct one. He appears to think that it certainly is caused by a burning gas; but I have always had a strong belief that it was a fluorescent effect somewhat resembling that seen in vacuum tubes. I must disagree with his statement that high-resistance lamps are liable to short-circuit across the internal terminals when they are first switched on. This was the case several years ago, but I do not think it is commonly met with in any well-made modern lamp.

I wish to point out that Profs. Forbes, Ayrton, and Silvanus Thompson have all fallen into the same error in ascribing the very perfect constant current regulation of various American systems of arc lighting, to regulating apparatus alone. They appear to have forgotten that in systems of arc lighting in series every arc light is a current regulator in itself, and this fact alone enormously facilitates the work of regulation of the governor or regulator common to the whole series system.

The President.

The PRESIDENT: I think we have present this evening Mr. Mortimer Evans, who read a paper before the Royal Society, on the radiation of certain lamps, and I would ask him to favour us with anything he may have to say upon the matter now under discussion.

Mr. MORTIMER EVANS: We are greatly indebted, I think, to Mr. Bernstein for his daring paper, and in so far as it advocates the use of lamps of moderately low E.M.F. it is, I think, a move in the right direction, though I cannot say I am prepared to support the introduction of an E.M.F. as low as he proposes. Mr. Evans.

With regard to this question of high and low E.M.F. lamps, attention appears to have been wholly directed for some years past to the production of lamps of the highest E.M.F. possible; indeed, lamps of 200 volts have been hoped for. With domestic lighting, however, and lamps of from 16 to 20 candle-power as a maximum, a high E.M.F. is, I think, a mistake; and, moreover, 10-candle-power lamps—a highly desirable size in many situations—while impracticable at 100 volts, are easy at 40 or 50.

Though the question of mains is doubtless the factor which has led to making a high E.M.F. desirable, still other means—an increased efficiency, for instance—would be its equivalent, and I do not think sufficient attention has been directed to this point. From a recent experimental investigation I have found that the amount of light yielded per unit of energy, when the temperature was maintained constant, has varied from 5 volt-ampères per candle when the filament has been allowed to remain black, to 2½ volt-ampères when a brilliant reflecting surface has been given to it, and, further, that the economy of working depended wholly upon the reflecting efficiency, if I may so term it, of this surface. This being so, it follows that if the same temperature or the same light per unit of surface be maintained with a less energy, both the current and the E.M.F. will be lessened and no increase of the mains will be necessary, and, moreover, lamps of 10 candle-power would thus be possible. In thus raising the efficiency of our lamps by improving the reflecting surfaces of their filaments we shall manifestly be tending towards a lower E.M.F., for a high E.M.F. filament when black becomes a low E.M.F. filament when made bright. It is not difficult to get a high E.M.F. lamp if the filament is black enough, but the increase of energy and E.M.F. is wasted as heat, and all filaments which lose their surface by blackening become wasteful in proportion.

Much improvement has yet to be made in the production of

Mr. Evans. high-reflecting surfaces, and I do not despair of seeing lamps run at less than 2 watts per candle without any increase of temperature; and I would strongly deprecate any tendency in this direction as most destructive to the life of the lamp itself, and also as tending very rapidly to injure its original efficiency.

Mr. Drake. Mr. BERNARD M. DRAKE: The general application of this system of driving in series has been put before you so well already that I have very little to say, but I quite agree with Mr. Crompton that there is very great difficulty in keeping the current constant.

I was connected with the Brush Company for some time, and had several lighting stations under my charge, from which we supplied arc lamps and groups of incandescents run on the same circuit, which is very similar to what Mr. Bernstein proposes. Every consumer had his own switch, so that the number of lamps in use constantly varied, and I must say that the difficulty of keeping the current anything like constant was enormous. As far as I have seen, there is no regulator for a constant current at this high electro-motive force that can be relied on to act quickly enough for incandescent lamps. The regulators all depended for their action on the current rising, and we found that before they acted there was a danger of bursting the incandescent lamps. Next, as to the safety devices which Mr. Bernstein puts as a shunt to each lamp, we tried several kinds of similar automatic arrangements to switch another lamp in circuit when the first failed, but we found they absorbed so many watts that it became a serious consideration in the general system; perhaps Mr. Bernstein will tell us what loss there is in the cut-out he uses. Further, it would appear that in the event of the shunt wire becoming deranged the cut-out would not act, and the whole series of lights would be put out. Comparing this system with that of accumulators placed in each house, it seems to me that if accumulators can, as we have no doubt is the case, be depended upon to work satisfactorily, there is no comparison in the ease with which the whole work can be carried on; all the complications are done away with, the lights can be turned on and off without affecting the remainder, there is no possibility of a whole district being left in darkness owing to the failure of the engine,

and the power required is less, as it can be kept working continuously. It will of course be seen as soon as the new Electric Lighting Act is passed, which of these systems finds most favour for central station lighting, but I venture to hope that the accumulators will at any rate come in for a fair share of patronage. Mr. Drake.

Professor GEO. FORBES: The great objection that I find to this system is the fact of the expensive nature of the switches. The drawing before us represents one of Mr. Bernstein's switches; and it will be remembered that, seeing the nature of its construction, if one of those switches is provided for every lamp, additional complications will be introduced. It is a most ingenious piece of apparatus. It has a great deal to do, and undoubtedly will answer its purpose. Mr. Bernstein was kind enough to show me the arrangement at his works: it is effective, and certainly seems to be very satisfactory, but there is no denying that it is an expensive piece of apparatus. It is quite possible, however, that it may be economical in the end to use, however generally, this comparatively costly switch, when we consider the enormous saving we may have in the conductors. Of one thing I have not the slightest doubt—that provided the lamp is of good lasting power and of a high state of efficiency, there are undoubtedly, at the present moment, a great many cases where it would certainly be desirable to introduce this system. Mr. Crompton and Mr. Drake have both told us that there is a difficulty about keeping a constant current. Now, totally independent of devices of compound winding, by which it has been proposed to keep up a constant current, I would simply remark that in the American machines for arc lighting it is satisfactorily done. Professor Forbes.

Sir DAVID SALOMONS: Perhaps I am one of the oldest experimenters in electric lighting. Mr. Preece went back to 1881; I think I can go back to 1874—to the elementary form of lamp, when a glass shade was placed over a saucer of oil—and I have followed up the various systems from that time to what is said to be the greatest perfection of to-day; I feel, therefore, that I can say a few words on the question raised by Mr. Bernstein. He will no doubt forgive me if I criticise his paper, for it is said that "no man is worth his salt that cannot bear a little probing;" Sir D. Salomons.

Sir D. Salomons.

and as I consider the paper laid before us introduces quite a new subject, or a subject newly treated, a little criticism is decidedly not objectionable. In the first place, in reference to what a speaker has just said, it is perfectly clear that a lamp may have an electro-motive force of any amount. I was probably the first to use 100-volt lamps for permanent lighting. I started with 50-volt lamps, but the disadvantage was that, unless the mains were enormously large, while several rooms were lighted the remainder were only imperfectly so. At the time I was laughed at, and told that 100-volt lamps were simply toys, and would never be of any use. It is perfectly true that in those days out of every 100 lamps ordered 80 used to go in a few days. However, I have lived to see the time when certainly 2,000 hours is nothing excessive, and 1,000 hours is quite commonly reckoned on. With the lamps I have in full use, my experience shows that a very large number—I dare say over 90 per cent.—have run much over 1,000 hours already, and I am sorry to disagree on this point with Mr. Preece, when he says that the lamps blacken on account of the smallness of the filament. The reverse *ought* to be the fact, and is so in practice, because with a larger carbon there is more surface for disintegration than in a 100-volt lamp, in which the filament of carbon is very small, while the area of the glass globes remain much the same in each case. I find that the 100-volt lamps are quite as good, if not better, than the lower-volt lamps of to-day; and I am glad that Mr. Crompton agrees with me, although some time back he was against the 100-volt, and in favour of the 80-volt lamp. Mr. Crookes has shown that a vacuum, although not perfect, is as good a non-conductor as can be found: it is almost a perfect insulator, and excepting lamps that have failed from air going in through flaws in the glass or from some other fault, there is no tendency whatever for the current to pass across the terminals. I say this in defence of the present lamps, because they have been considerably improved over the earlier ones. The dangers of short circuits are practically nil; for 2½ years I have run without a single short circuit or break down at all, which speaks highly for the parallel system, where the servants are, and indeed anybody in the

house is, allowed to replace lamps, insert motors, and do almost what they like. Sir D. Salomons.

The saving in the cost of conductors, as Professor Forbes says, is no doubt very advantageous under Mr. Bernstein's system; but I see no advantage whatever in the lamp itself, unless its life far exceeds what is now accepted as a long one, say 2,000 hours, for 9·75 ampères at 7·7 volts, compared with a 100-volt lamp taken as a standard, with 7·8 ampères, will give the same light, although we may hear more directly of the great loss which appears to me must ensue before you come to the work done in the lamp itself: in other words, 7·8 ampères give the same light with less loss, as compared with 9·75, if conductors are left out of the question. A disadvantage that I can see—and it is a very great one—is the possibility, if the lamps are all connected as in arc lighting, of a short circuit taking place which would put them all out, and which would be very objectionable in the case of street lighting or of public buildings. If that objection could be got rid of or simplified to a very great extent, the system would have a large scope in a great number of cases. Mr. Crompton pointed out how sometimes the human body got introduced into a short circuit; and I will relate an instance of the kind, which may be of interest to manufacturers and installators. I will not guarantee the whole of the particulars as being accurate, but I give them as they were put to me, and generally the story is true. There is a shop a few doors from the Inns of Court Hotel, which many will remember is lighted by arc lamps, fed, I believe, from some place in Whetstone Park. A man went to look in at the window of the shop, and was suddenly knocked down by some unseen agent; a policeman thereupon went up to complain to the manager inside, but he was knocked over like the first man. Had the place been attacked by rioters, the shop would have been well guarded. The reason of all the mischief was that the whole of the framing of the shop was of metal, also the area frame in front, and one of the arc lamp leads had somehow become connected with the framing. This is a condition of things which some manufacturers will not unfrequently find in practice, and they should take care to avoid the accidents to which it may give rise.

Sir D. Salomons. I have found that the cost of lamps per year has become much less than it was formerly, and that the Swan lamp wears as well as any other. Much has been said about the Woodhouse and Rawson lamp, which is extremely good; but as regards the Swan lamps, I do not think, excepting experimental ones, which I do not count, that out of 200 to 250 in use, and of which 40 have been continually burning, that more than 7 have gone in 2 years, which speaks very highly for their manufacture. As Mr. Bernstein has said, great danger exists in breaking the circuit, but, in working, this danger could be completely overcome if manufacturers would have the switches made of some non-combustible material, such as china, instead of wood. I will not take up the time of this meeting any further. There are many points upon which members will no doubt wish to make remarks, and I feel that any one who can say a few words on the subject, and elicit answers from Mr. Bernstein, will confer some benefit on us all, because it will set us thinking on a new system; and even though that system may prove to be worthless or not practical, very often discussion upon such matters leads to the great developments of science of the age.

Professor Ayrton. Professor W. E. Ayrton: Much has been said this evening about the question of the cost of lamps: I do not think that members are sufficiently well aware how very small is the cost, in an electric light installation, of the renewal of lamps. Some little time ago my colleague and I were desirous of ascertaining the most economical potential difference to be employed with a certain type of incandescent lamp, and we went into the question very carefully, and found that, taking into account the cost of the power as well as the cost of renewals, the cost for lamp renewals was but a comparatively small fraction of the total cost of producing the light per year. As to the question of danger, I think a great deal too much is made of it, and I am glad to hear Mr. Bernstein advocating high potential differences. People run away with the idea that if 2,000 volts are used they necessarily will be killed. That is not the case at all: the real fact is, it is not merely the difference of potential which settles the danger, but the constancy or inconstancy of the current. I use

Professor Ayrton.

the word "constant," and I am glad that people are beginning to use the term "direct" when they mean a current which does not alternate, because it is just as important to distinguish between constant and inconstant direct-current dynamos as between direct and alternate-current dynamos.

If you have a really constant-current dynamo producing 2,000 volts, I do not think it is particularly dangerous. To obtain great constancy, we must have a great number of pieces on the commutator, and the machine must be constructed with great symmetry, and then I believe we may use with perfect safety very much higher potential differences than it is supposed are permissible at the present moment. Another question is that of maintaining a current constant in a circuit. Doubt has been thrown on the possibility of doing this, and I was very glad to hear Professor Forbes mention how admirably the Thomson-Houston succeeded in attaining this result. I also had the opportunity at the Inventions Exhibition of being permitted to turn off a very large number of arc lamps in the Chinese Court, and I must confess that I did not see the slightest flicker in the remaining arc lamps, which were all in series. This proved conclusively that their system of automatically moving the brushes operated successfully in maintaining a constant current. As to the difficulty of a large electro-magnet being worked by a change of current, that has been got over in the Thomson-Houston system by the telegraphic method of using a relay: a change in the current worked a relay which operated a powerful electro-magnet, which latter moved the brushes. There is a great difference between trying to maintain a constant current and trying to maintain a constant difference of potential. If a constant current can be maintained—and it certainly has been--then it can be maintained throughout the whole circuit, because the current is the same everywhere; but if the potential difference is kept absolutely constant at the terminals of the dynamo on the parallel system, then, as is well known, a constant difference of potential cannot be maintained anywhere else with a simple circuit, and only approximately when a complicated system of feeders is resorted to. Therefore one problem is a physical probability, and the other is a physical impossibility.

Professor Ayrton.

There is one great use that I see for these low-resistance lamps, and for that reason alone I think we ought to thank Mr. Bernstein very much for his efforts, and congratulate him on the success that they have met with. The question is frequently put to me with regard to temporary installations: "I want to light up a room for to-night, or a night in next week: how many accumulators must I use?" The answer is, probably, 26. But I am then asked whether such a large number of accumulators is wanted for three or four lamps. Of course you know that the electromotive force is necessary even for a few lamps. But now I can answer, "Four accumulators," and I know that such an answer will lead to the use of incandescent lamps for temporary installations in many cases where it would have been impossible previously. We all know quite well that the weight of accumulators necessary to be employed to produce a given amount of energy in a given time will be the same, whether the accumulators consist of a large number in series, or a smaller number of large accumulators and not so many in series; but there is a considerable difficulty in having to quickly connect up a large number of small accumulators, and great danger that one or other of the accumulators may be left loose. Now that it is possible to have three or four 20-candle lights by using three or four fairly large accumulators, I feel certain that people will be willing to have these lamps, which they would not dream of doing if they required 55 accumulators to produce 110 volts.

As to the new word suggested by Mr. Bernstein, it is sufficient to reply that another word has been constantly used this evening by many speakers, probably unconsciously, viz., the word "efficiency." It is the well-known word for the candles divided by the watts—the number of candles per watt—and as there is already one word used for the purpose, I hardly think it necessary to introduce another. But while I do not propose to avail myself of Mr. Bernstein's new word, I hope to have the pleasure of using his new lamp.

Professor Thompson.

Professor Silvanus P. Thompson: Professor Ayrton has sung the praises of the constant-current arrangement, and has saved me something which I might otherwise have had to say. I have

Professor Thompson.

long been looking forward to the possibility of working with a constant current instead of constant potential, as being much more economical whenever the current has to be carried a long way from the dynamos to the lamps. I hail this lamp as being a step towards the solution of that problem. If it is possible to work with a constant current, a great many difficulties disappear. If the current is kept always at one value—say 10 ampères—and is never anything else, then you will never need more than one kind of switch and one cut-out; the lamps can be all alike, and no trouble need be taken to select them, as is necessary when working with lamps of constant potential. But the point to me of greatest interest is the constant-current dynamo. If dynamos are to be made to work with a constant current, then the very thing which comes in as your worst enemy in almost every other case—self-induction—comes in as your friend. In an alternate-current machine self-induction is very harmful—is as bad as it can be. In a constant-potential machine it is bad, but not so bad; but in a constant-current machine the self-induction is positively your friend. Every coil, every electromagnet in the circuit, reacts upon the current and steadies it. It is more easy to maintain a constant current in a single circuit than a constant potential in a branching one, because the self-induction acts as a fly-wheel on the system. It is quite true that in America they have very constant currents indeed in the arc-light circuits of the Brush and of the Thomson-Houston systems. I have tested the Thomson-Houston system and switched out lamps. I must point out one fact that has apparently escaped Professor Ayrton's notice, viz., that long before the automatic adjusting mechanism which shifts the brushes had time to act, the current had regained its constant value. Having seen equally good working on Brush arc-light circuits with 10 ampères of current, I believe it to be, not a theoretical, but a practical problem. I believe that a good constant-current dynamo will very soon be among the good dynamos available. Almost all the progress that has been made during the past three years in dynamos — and it has been splendid progress — has been in the direction of perfecting the *constant-potential*

Professor Thompson.

dynamo; but now I think the turn of the *constant-current* dynamo is come.

I noticed that Mr. Preece objected to new definitions, but after his objection I was rather astonished to hear him call the Bernstein carbon tube a "filament." What is the fact? Some one has some time coined the term "filament," which may be convenient when one is speaking of a thin shred of tarred fibre carbonised; but the name having been invented, we have all, like silly sheep, followed the fashion of calling all carbon conductors inside lamps "filaments," whether they really were filaments or not. As for the conductor in Mr. Bernstein's lamp, I understand it to be not a filament at all, but a tube.

Major-Gen. Webber.

Major-Gen. WEBBER: I should like to ask Mr. Bernstein one or two questions of a simple character, which I hope will not infringe upon the secrecy of manufacture. First, would he kindly tell us the manner of surrounding the platinum wires with the proper kind of glass, and what the proper kind of glass is? Secondly, what is the nature of the difficulties which he mentions in connection with large-resistance lamps, in sealing the wires air-tight into the glass, it being of course, as we know, far easier to seal effectually a thin than a thick wire? I hope Mr. Bernstein will be good enough to enlighten us on those two points in his reply.

Mr. W. H. PREECE: It had been arranged by the Council that my paper on "Long-distance Telephony" should be given at the next meeting, but I am perfectly ready to postpone it in order that Mr. Bernstein's paper may be further discussed. I beg to move that this discussion be adjourned till the next meeting.

Major-General WEBBER: I beg to second the motion.

The motion, having been put by the President, was carried unanimously.

Sir DAVID SALOMONS: Would it not be desirable that Mr. Bernstein should reply this evening to so much of the discussion as has taken place, in case members now present should be absent at the next meeting?

Mr. Bernstein.

Mr. A. BERNSTEIN: I am afraid it is too late to answer all the various questions which have been put forward with reference to the subject. I was pleased to see that the matter which I have

Mr. Bernstein.

brought before you has been the cause of such an interesting discussion, but I find it impossible to enter into all the details of that discussion at present. The question was asked whether I have ascertained by experience that this lamp has a longer life than other lamps. I must confess that I have not been able to make tests of such duration as would entitle me to say anything definite on this point, so I would rather not say anything. But there is one way of approximately trying whether a lamp is likely to be durable. The experiment consists in gradually increasing the current until the lamp gives out, and noting the excess of current or candle-power, at the last stage, over the normal current or candle-power. I shall do this now by switching out resistance, which is in circuit with the lamp. [*The current was increased to* 14 *ampères, but the lamp had not given out up to the time of the meeting being adjourned.*]

A ballot then took place, at which the following were elected :—

Member :

William Henry Radcliffe Saunders.

Associates :

Sydney Evershed. | A. L. I. Rebeiro.

George Sutton.

Students :

Eustace Frederick Calland. | John Joseph Hatt.

Ernest Nevill Giles. | Thomas Percival Wilmshurst.

The meeting then adjourned.

The One Hundred and Fifty-fifth Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, April 8th, 1886—Professor D. E. Hughes, F.R.S., President, in the Chair.

The minutes of the previous meeting were read and approved.

The names of new candidates for election into the Society were announced and ordered to be suspended.

The following transfers from the class of Associates to that of Members were announced as having been approved by the Council:—

J. C. Chambers.	Walter Emmott.
Alfred Coleman.	W. B. Esson.

Hubert M. Musgrove.

A temporary installation of arc and glow lamps in series, fitted up by Messrs. Laing, Wharton, & Down, and the Bernstein Electric Lamp Company, and worked by a Thomson-Houston dynamo, was exhibited.

The President. The President having invited Mr. Bernstein to make any additional remark he desired upon his paper before the discussion upon it was resumed,

Mr. Bernstein. Mr. Bernstein said: I beg permission to say a few words in regard to the display of lamps which is exhibited to the meeting to-night.

Shortly after the last meeting, Mr. Wharton, of Messrs Laing, Wharton, & Down, made the proposal to me of exhibiting a number of arc lamps with my new incandescent lamps in circuit, the current being derived from a Thomson-Houston dynamo, in order to demonstrate the regulating quality of these dynamos. Although I had no lamps on hand for the current of the dynamo, viz., 6·8 ampères, I considered the matter of such interest that I resolved to have some special lamps made, which were only finished to-night. At the close of the discussion I shall beg permission to make some experiments with regard to the glow lamps, and I

suppose Mr. Wharton will have the kindness to demonstrate the regulation of the dynamo. Mr. Bernstein.

Mr. C. J. WHARTON: When this very interesting paper was read by Mr. Bernstein, and the discussion upon it was commenced, I was unfortunately absent, but was ably represented by one of our experts, who gave me a faithful report of what took place. The Thomson-Houston system (in which my firm is so very much interested) came very much to the front. Some speakers said it would not do what it was represented to do; while others—to whom we must tender our thanks—spoke in its favour, and said that they had themselves seen it, not only at the Inventions Exhibition, but at other places, where the Thomson-Houston machine worked in a perfectly automatic self-regulating manner. I therefore considered it important, if possible, to show by actual experiment and demonstration what the system would do. I communicated with Mr. Bernstein, and, having obtained the necessary permission, we have brought the installation together which is now before the meeting. I think, from what can now be seen, and from the experiments that Mr. Bernstein will make later on by switching arc and incandescent lamps in and out, that it will be agreed that there is certainly a very great future for low-resistance incandescent lamps running on an arc circuit, *i.e.*, if a really automatic self-regulating dynamo is used, such as the Thomson-Houston, which is not only self-regulating for resistances, but also for variations in the speed. It will not be possible to show great variations in the speed to-night, as we have a compound engine by Messrs. Hornsby running the dynamo; but its perfect regulation will be illustrated by switching arc and incandescent lamps in and out. I must, however, say that the machine is now running almost on short circuit; it is working these few lamps, which take up very little of its E.M.F. besides that taken up by the two lamps at the dynamo. The machine is running at its normal speed at the present moment, giving out the normal current; it is an 18-lamp machine, and the whole can be switched on and the current will remain exactly the same. Some speakers said that it was quite easy to regulate with arc lamps in circuit. Well, how is it that it is not generally done? Because in every other system, if you cut out arc lamps, either the speed must Mr. Wharton.

Mr. Wharton.

be decreased or resistance must be put in. With the Thomson-Houston machine no attention whatever is paid to it; but the engine must, of course, be governed so as to develop more power as the lamps are put in, and correspondingly, of course, less when lamps are cut out. Incandescent lamps are run on the Thomson-Houston circuit every day; many thousands of them are running on the arc circuits in the States. They were running at the Inventions Exhibition on the circuit referred to by speakers last meeting, on which twenty arc lamps were switched out without damage to the incandescent lamps also on the same circuit. At the present moment I am engaged in fitting up an installation in a West of England town where quite half the load will be in the shape of Thomson distributors, where incandescent lamps will run in series with arc lamps, not exactly in the manner shown this evening, but six in parallel, each parallel taking the place approximately of one arc lamp, and capable of being switched in and out without any variation at all. The man in the engine-room, in such a case, knows nothing about the lamps varying in number except that he sees that the regulator on his dynamo is working. I am not quite sure whether I shall be able to switch in all the lamps we have here to-night, because just before starting an accident happened: a portion of the temporary arrangements giving way during one of the very heavy showers which fell about that time, water got to the armature, and one of the brush-holders was partly broken. The brush-holder is not very important, but I do not like switching on too many lamps on a 1,500-volt machine with the armature soaked through. But with the few lamps that can be shown, conclusive proof will be presented that anybody can switch the lamps in and out and there will be a perfectly automatic regulation resulting in the current being kept absolutely constant with a varying E.M.F.

The President.

The President: Before the discussion is commenced, I should like to remark that I have down the names of ten gentlemen desirous of speaking to-night; and therefore, as Mr. Bernstein has given me notice that he will require half an hour for his reply, it is necessary that the speakers be as concise as possible, in order to get through the discussion in time.

Professor J. A. FLEMING: In the discussion on Mr. Bernstein's very interesting paper that took place at the last meeting, a very large number of points were touched upon by the various speakers who then addressed the meeting. I will try to be as brief as possible in my remarks upon those few points that seem to me to call for further observation. Professor Fleming.

In the first place, I must add my protest to that of Mr. Preece at the attempt to introduce a new term into our electrical vocabulary. One thing that certainly ought to characterise scientific nomenclature is that we should have one word to mean one thing, and not, as in common language, half a dozen meanings to one word. The word which Mr. Bernstein has proposed to represent the reciprocal of watts per candle-power, viz., "strain," seems to me to be an unadvisable addition to our nomenclature; we have already a perfectly definite meaning attached to the word "strain" in scientific language. The word "electric strain" has been used by Maxwell to represent electric displacement; the word "strain" was taken by the late Professor Rankine to represent displacement in opposition to a stress of some kind or other, and that meaning is a perfectly definite one; it does not seem advisable, therefore, to add another. The reciprocal of the number of watts per candle-power is the number of candles per horse-power, and it does not seem necessary to have another word to signify the reciprocal of watts per candle-power; it is most desirable not to duplicate words if possible.

Then Mr. Bernstein says: "From certain analogies well known in physical science, we may conclude that a black, sooty carbon will radiate more heat than a carbon of a dense greyish surface raised to the same temperature, and consequently the former will require a larger supply of electric energy to maintain it at the same temperature than the latter." We all know perfectly well that by the law of exchanges bodies which absorb best, radiate best—the body radiates those rays which it absorbs—and that therefore the best surface for emitting light and heat is a black, sooty surface; and the one thing that makes carbon the best substance that can be used in an incandescent lamp is the fact that it is a good absorber of every kind of ray, and therefore

Professor Fleming.

radiates well. There is an important point in connection with the characteristic emission of different kinds of carbon: they emit light and heat differently; *i.e.*, there are very different proportions of radiation of light and heat in different kinds of lamps. Some time last year—I think in July—there was an interesting paper in one of the electrical journals by a Mr. Peukert on the different proportions of light and heat radiated by incandescent lamps. I think that those experiments were not carried out as completely as they might have been, yet they were exceedingly interesting, and showed the fact that the different classes of filament expended the total energy which was wasted in them in different kinds of radiation; some filaments gave out more in light than in heat, the proportion being different in each. The thing to be aimed at, of course, is a filament which will get rid of its energy as far as possible in eye-affecting radiation, and I do not know whether Mr. Bernstein will be able to give us any information as to whether his filament is excellent in this respect, but it is certainly a very important thing to know. The chief thing that makes a filament a good filament is not its colour, but the nature of the carbon of which it is made. What we want to do in incandescent lamps is to obtain a carbon of as refractory a nature as possible, so as to bear a high temperature, and the very spongy kinds of carbon are generally kinds that will not bear a very high temperature without volatilisation going on.

I notice a statement in the paper that "the thinner the filament the greater the danger of flaw in it." I must say that I cannot agree with that remark at all. The danger of a flaw depends entirely upon the mode in which the filament is made, and finer filaments may be longer-lived than thicker ones; there is nothing in the diameter alone to show that it will have a short life, but the thing depends entirely upon the mode of manufacture and the success of attempts made to obtain absolute uniformity in the process of manufacture. I have lamps in my laboratory of very fine filaments indeed, and, compared with thick filaments, they have very long lives. The necessary thing to have, is a perfectly homogeneous filament, and not one with its structure unequal in radius in different parts. Also, Mr. Bernstein

states that in "high-resistance lamps, even if worked at a strain of no more than four to five watts per candle, the carbon filaments are disintegrated, that the resistance of the lamps consequently increases, and that the glass bulbs begin to blacken, we are led to suppose that other forces must be at work which produce the destruction of the lamp. These forces are of an electrical nature, and their existence is easily explained if we consider that an electric glow lamp is at the same time a vacuum tube." I am inclined to think that the forces that are at work in the disintegration of the filament are chiefly of a thermal nature—that the disintegration is simply due to the high temperature of the filament, which produces what may be called a molecular scattering of the filament at the point where it is hottest; it is not an electrical effect, but one of actual temperature at that point. Professor Fleming.

In regard to the appearance of the blue colour seen in a lamp when it has been raised to a very high pressure, Mr. Bernstein seems to infer that this blue flame is due in some way or other to the presence of carbonic oxide in the lamp. I must say that I cannot agree with the theory that is here put forth of the blueness in the lamp. It is obvious that no lamp could have any useful life at all which contained so much residual oxygen in it that the mere raising it to a high temperature got rid of the oxygen in a sufficient amount to reduce the carbon to carbonic oxide. It seems to me that the effect is altogether one of phosphorescence—that the carbon, when pressed to an excessively high temperature, emits radiations which produce phosphorescence in the glass. I notice that when lamps are suddenly placed on a circuit and raised to a very high temperature so as to produce the blue phosphorescence, in lamps of a horse-shoe filament the appearance which is called a molecular shadow is produced, which shows that there is a projection of the carbon molecules against the glass in straight lines; and I cannot help thinking that this blue appearance is really phosphorescence in the glass.

Reference was made last meeting as to the exaggeration that had been indulged in with respect to the dangers of the series system. I quite agree with the remark of a member that the dangers of the two systems are about equal. Many of us, I think,

Professor Fleming. have been prone, in past days, to exaggerate the danger of the series system of high electro-motive force and small current, and to minimise the danger of low electro-motive force and large current. There is no doubt about it that when you have a large amount of energy, say 2,000 volts, being transmitted, you need to take specific precautions to insure against danger from fire or against danger to life. I think that the chief difficulty that would be found in working with a series system such as that now described to us is the difficulty of insulating the underground mains. Experience in America in this respect is not any guide to us here in England. In the incandescent systems in use in America the conductors are chiefly overhead; in the large systems of arc lights there, the conductors are simply the ordinary wires, carried on telegraph insulators overhead, and in that dry climate the difficulties of insulation do not at all seem to interfere with such work as that. But we certainly know that we shall never be in a position in England to carry out a system of overhead light wires as they do in America; and therefore, if we propose any such system as that suggested by Mr. Bernstein, we must be prepared to put the conductors underground. Then the moment that step is taken difficulties arise, because the insulation is not merely increased in proportion to the potential, but the tendency of the current to break through the insulation is proportional to the square of the electro-motive force; and therefore, in dealing with an electro-motive force of 2,000 volts, the insulation required would certainly be more than twenty times that of 100 volts. If, however, these difficulties can be overcome—and they certainly are not insuperable—then I think we may look forward to the prospect of having incandescent lamps in series in the manner in which Mr. Bernstein has shown us; and I think we must certainly congratulate Mr. Bernstein on his boldness in attacking this problem, and for the very interesting paper he has brought before us.

Mr. Mordey. Mr. W. M. Mordey: I was very desirous of saying a few words at the close of the last meeting, because I feared the discussion on this interesting and able paper on a most important subject was likely to be closed without any sufficient reference

being made to work that had been accomplished in a direction very similar to that proposed by the author. As supporting the author's views as to the possibility of easily carrying out a series system of working, it seemed to me that some allusion should be made to the fact that several rather extensive installations of electric lights had been made over considerable distances, notably at Brighton, Eastbourne, and Hastings, in this country, and at Temesvar, in Hungary. Although in these installations lamps of such low resistance as the author has been successful in constructing have not been used, I believe that at Eastbourne lamps carrying 3·3 ampères were in use; that is to say, three lamps divided up the current of 10 ampères from Brush dynamos. These lamps were made by Mr. Swinburne. I will not occupy your time by further remarks on this question of actually successful installations. My object is to draw attention to their existence; and as Mr. Wright, of Brighton, Mr. Sayers (who conducted the work at Eastbourne), and Mr. Swinburne, are all present, I hope that we shall hear some account of their actual experience. Mr. Mordey.

The use of lamps in single series would often be desirable, where it is desired to turn lights on or off one at a time; but I think the author has unnecessarily confined himself, in his proposed distribution system, to recommending such lamps. One of the great advantages of series working is that lamps of various kinds can be used, as well as other apparatus, such as motors. It would often be convenient to use lamps in multiple series in conjunction with such lamps as the author has constructed. It is a convenience peculiar to the series system that lamps of any E.M.F. or candle-power can be used, so long as such a number are placed in a group as will give each lamp its proper current. And it must not be forgotten that the smaller cost of cut-outs and switches, and the convenience of wiring with small wires, which are not unsightly, will often tell in favour of multiple-series working, as distinguished from simple series.

With regard to the question of the life of lamps, I share the common belief that it is of the utmost importance that lamps should have long lives. I hold this opinion in spite of Mr. Preece's statement that at present lamps last too long, and

Mr. Mordey. that it would be better to work them at a higher efficiency and with a shorter life; and also in spite of Professor Ayrton's statement that the cost of lamp renewals is an insignificant item in the total working expenses, even with lamps at five shillings each. Quite apart from the cost, there are very serious objections to short-lived lamps, not the least of which is the inconvenience and danger of a room, or perhaps a railway carriage, being placed suddenly in darkness. I think if lamps of high efficiency and short lives are used, it will be an absolute necessity to provide duplicate lamps or filaments, and to use automatic means for throwing a second lamp, or a second filament in the same globe, into circuit should the first one give way. Now, while believing that there is a very great future for the series method of working, I do not think that method is the best for the lamps, whether they be of high or low resistance. There is a reason, which has not been alluded to in the paper or in the discussion, and perhaps has escaped notice, why series lamps are of necessity shorter-lived than parallel lamps. The cause of this difference is that lamps worked in parallel take less current as their filaments become weakened and thinned by age. Their resistance rises, and in this way they possess a considerable preservative power. Lamps placed in series do not possess this power. On the contrary, and especially when in single series, as they are always traversed by the same current, whatever their resistance or state of incandescence may be, the process of disintegration becomes more and more rapid, instead of being retarded, by increase of resistance. These lamps will not, it will be seen, suffer under the disadvantage of giving less light when old than when new. Their candle-power will increase with age, and they will in consequence approach their death with continually increasing rapidity. I do not, however, think that this objection in itself will be sufficient to stand very much in the way of the application of the system.

The author is, I think, quite justified in assuming the possibility of maintaining a constant current in the conductors. After the statements on high authority already made in this discussion there can be no doubt on this point. And it must not

be lost sight of that the maintenance of a constant current is a physical possibility, while constant potential in a distributing system of conductors is not a physical possibility. I may say that perhaps the only way in which constant potential difference can be maintained is by keeping a constant current, and even this requires that the resistance of the lamps must be constant. Mr. Drake had, indeed, stated that it was difficult to keep the current constant even for arc lamps, and that the Brush regulator for this purpose did not answer. Mr. Drake had been unfortunate in his experience—perhaps he had not been able to look after the thing himself; at any rate, Mr. Sayers had been quite successful in using this apparatus at Eastbourne, even for glow lamps. The instrument in question works very well. In the works with which I am connected, the shop lighting and the testing of arc lamps is carried out on the circuit of a large dynamo which is controlled by one of these regulators, the lamps being turned on and off just as they are required. Mr. Mordey.

I have never been able to understand the attitude of those who so strongly oppose distribution at high tension. The advantages of such a system are enormous. The author of the paper has done a great service by giving prominence to these advantages at the present time. He could not have chosen a time better suited for doing so, as all questions of distribution are now attracting attention; and, thanks to the teaching of Professor Forbes and others, it may be said that electrical engineers are now in a position to consider all such questions on their merits. The enormous outlay in conductors necessary under all parallel systems should incline those who have to do with these matters to look with renewed hope on the series system as showing a way out of many of their difficulties—a way which has been too much neglected. Only those who have actually to plan and work installations know how great is the cost of conductors in connection with low-tension parallel distribution, and how much electric lighting is being retarded by this one difficulty of the cost of mains.

I do not, however, share the opinion expressed by the author that in ships, and generally in compact installations which are

Mr. Mordey. near the dynamo, high-tension is likely to displace low-tension working. In such cases high tension does not offer any great advantages. Even in the matter of cost of conductors this is the case, as a comparatively large and even unsightly conductor has to be taken to each lamp, instead of a small wire which can be readily disposed of. The cost of switches and automatic cut-outs will also in such cases tell against the series system. These difficulties, however, are of much less importance for long-distance working, where the cost of mains is the all-important consideration. To give some idea of how great are the advantages of the series system in such cases, I may be allowed to give some figures showing what can be done with existing apparatus. The author recommends the use of a No. 6 copper wire for conductors carrying the current of 10 ampères. There can be no doubt that such a conductor is large enough for almost any circumstances. It will probably be found that it is too heavy for real economy, as the loss of potential would be very small. This wire has a resistance of 1·4 ohms per mile. The loss of potential would therefore be only 14 volts per mile—this is equal to 2·33 60-watt lamps; or, to put it in another way, the loss in 750 yards is equal to one 60-watt lamp only. The current-density is only 309 ampères per square inch. But as the author recommends this wire, it may be taken for the purpose of illustration. And I think we may take a dynamo giving 3,000 volts and 10 ampères as a practical machine. This output is nearly reached by the largest Brush dynamo, which works very satisfactorily, and without any difficulty or trouble whatever. Such a dynamo would maintain the current of 10 ampères through a line consisting of 215 miles of No. 6 wire. For every 750 yards reduction of length a 60-watt lamp can be inserted. It is often a safe rule to put down mains which allow of a conductor efficiency of 90 per cent; that is to say, 10 per cent. of the energy received from the dynamo is lost or expended in the mains. If the circuit of the dynamo in question is reduced to 20 miles we should have such an efficiency. On such a circuit it would be possible to have 450 60-watt lamps, or one lamp every 70 yards. This is surely practicable, and affords an instance of how easy and economical it is to distribute

lamps on the high-tension series system. May I put it in another way, as an illustration? With such a machine it would be possible to work an arc light in a lighthouse 210 miles from shore, using an earth return, or half that distance using a wire return, if a No. 6 conductor, suitably insulated, could be laid. Mr. Mordey.

The two main objections advanced by the opponents of high-tension working are the difficulty of maintaining the current constant, and the supposed danger of the system. As regards the former, I need not say anything further; but as to the question of danger I may be allowed to say that I think this has been greatly exaggerated, and that the author has dealt very satisfactorily with the subject of safeguards. For four or five years I have been engaged daily in working and testing high-tension dynamos under conditions which were often the least favourable to safety. In such work it is often unavoidable that the circuits should be more or less of a temporary and exposed character. The care cannot be taken which would be a matter of course in any permanent installation work. The attendants are often workmen and pupils possessing little or no knowledge of electrical principles, and yet during the whole of that time there has never been a single accident or a case of personal injury to any one, in the works referred to, from an electrical machine or circuit. This leads me to believe that, under proper supervision, and with the precautions which would be taken in permanent work, there is no reason to believe that the use of large E.M.F.'s is dangerous in the ordinary sense of the word. I may add that in the works referred to, although there have been no accidents from the electrical machines, there have been several cases of injury from machinery other than electrical. The opponents of high-tension working, I think, exhibit too extreme caution. If they acted on such notions logically in other things, and were able to carry their case, they would sink into a state of almost absolute zero; there would be practically very little motion, and what motion there was would be very slow. Cabs and omnibuses would disappear from the streets, and express trains would become a thing of the past.

I do not think Professor Fleming is right in supposing that

Mr. Mordey. the danger of rupture of insulating materials increases as the square of the electro-motive force. I should be glad to know whether there is any evidence on that point. My experience in practical working certainly has never revealed anything that would confirm such a supposition. Is the statement founded upon theory or experiment?

One of the most important details dealt with in this paper is the construction of safety devices or cut-outs. One of the arrangements described—that of using a fuse in the shunt—does not appear to be very practical, but there is no difficulty with electro-magnetic cut-outs. These are in successful use in arc lamps at the present time. The cost of such arrangements need not be serious, and with regard to the point raised by Professor Forbes and others as to the energy absorbed in them—if I am not infringing Mr. Bernstein's rights in alluding to remarks made in the discussion—I may say that the energy so absorbed is entirely under control, and can be reduced to almost any extent by suitable winding. For instance, in the cut-out of the Brush lamp the energy absorbed is only five-eighths of a watt.

It would be of great interest to hear something about any alternative methods of distribution, where long distances are concerned. There is, I think, only one which appears to be likely to enter into serious competition with the pure series or multiple-series system of direct supply. I refer to the secondary-generator system. It can probably be shown, whether the question is considered from the point of view of economy of energy and of outlay, or with regard to safety, or to the power of self-regulation, that in all these matters a comparison between the direct series system and the secondary-generator system will reveal the substantial advantages possessed by the former.

The President: I see that we are favoured to-night by the presence of Mr. Swan, and perhaps he would wish to say something on this very interesting subject.

Mr. Swan. Mr. J. W. Swan: I do not think, Mr. President, that I am one of the ten or twenty gentlemen whose names you have on your list as desiring to take part in the discussion this evening, and yet I cannot entirely decline the invitation which you have

addressed to me, and which the meeting has so warmly supported. **Mr. Swan.** The paper before the meeting naturally attracted my attention. I have read it with very great interest, and I think we all owe a deep debt of gratitude to Mr. Bernstein for the admirable manner in which he has treated a very much neglected subject. The point of interest in connection with series lighting is its relation to a wider distribution of electricity than is practicable by the methods hitherto almost invariably used; I mean the multiple-arc method, or that ingenious composite method—proposed, I believe, simultaneously by Dr. John Hopkinson and by Mr. Edison—the three-wire system. By neither of those methods do we get the power of spreading our lighting wires as far as it is desirable we should have the power of extending them. One has involuntarily turned to series lighting to find, if possible, a way of escape from the restrictions of the prevailing methods. The difficulties of the case have, I think, been very fairly stated by Mr. Bernstein, who has grappled with them manfully, and even heroically. He has spoken of a lamp which has an exceptionally low resistance. I am inclined to think that he has gone to an extreme in proposing a lamp to carry so large a current as 10 ampères and of so low a resistance as 0·7 of an ohm. It seems to me that, without deranging the general project materially, you could with some advantage diminish the current and increase the resistance. The unit of light could remain unaltered, or it could be diminished, and I think usefully diminished, even to 10 candles. There would be less heat carried away and wasted by the terminals, and in the event of the breakage of a lamp a less voluminous arc would be formed.

The efficient and economical insulation of the conductors is one of the great difficulties of the case. I was therefore very glad to hear Mr. Mordey say that in practice he had found that an electro-motive force of 2,000 volts, or even 3,000 volts, was not too great to be practically dealt with. That difficulty being removed, I think we can very confidently face all the other difficulties, the chief remaining one being in regard to what have been called the automatic "cut-outs"—the automatic "circuit-closers" or "circuit-keepers" would perhaps be the more correct

Mr. Swan. description of this essential apparatus. I have not had the advantage of seeing the automatic circuit-keeper of Mr. Bernstein, but I hope it does provide the safety—the infallibility of action—which is absolutely necessary in a system of series lighting. Not only is infallibility of action necessary, but economy of construction is also necessary, and the two things being somewhat in conflict with each other increase the difficulty. It is absolutely necessary that the automatic circuit-keeper should be infallible in its action, because the maintenance of a long line of light depends upon that; and it is also necessary that this apparatus should not cost too much, because one must be attached to every lamp, and, in addition, one of larger size must be placed at the inlet and outlet of the current to the house or building. Considering that one of these circuit-keepers has to be attached to every lamp, anything expensive would be a very serious addition to the cost of an installation. The appearance of an automatic circuit-keeper is also an important matter. It would not do to have anything cumbrous or unsightly fixed to the lamp. I hope Mr. Bernstein has satisfactorily overcome that difficulty. I hardly think I am warranted in entering further into the discussion, considering that I am not one of those entitled by arrangement to speak this evening; I therefore make way for others.

The President: I have to thank Mr. Swan for his very practical remarks, and I am sure we were all very glad to have heard them.

Mr. Wright. Mr. A. Wright: I have been very much interested in Mr. Bernstein's paper, as it deals with a part of a very general system of electric lighting with which I have been connected for the last three years at Brighton—a high-tension system. The general system is the multiple-series; but in the system at Brighton and elsewhere we are not confined to the use of lamps using 10 ampères, but may use lamps of all currents—1, 2, 3 ampères, and so on—the only requirement being a constant current. As some doubts have been expressed with regard to the possibility of getting a constant current, I may say that it is perfectly practicable, and is done every day at Brighton over three or four

circuits extending some $8\frac{1}{2}$ miles. The danger of high tension Mr. Wright. has, in my opinion, been greatly exaggerated by the low-tension electricians. We have never had the least shock or danger arising from the use of 1,800 volts through any of our circuits. The most important point, of course, is high insulation, and the speedy remedy of any fault that occurs. It is most important that the means by which faults can be found out on long circuits—on which, of course, the high tension is eminently useful—should be understood. Finding out a fault while the current is flowing through a wire, in my opinion, is the most useful form of fault-finding, because in a general distribution of electricity a current will always be flowing through the wires, and by the electrometer method it is perfectly possible to find the position of a fault under such conditions, and also its amount. It is hardly necessary for me to say that in a series system the difference of potential between the positive pole and earth at the generator or at the station is always equal to the distance of the fault in volts from the positive pole of the dynamo. For instance, if we measure the potential between the + pole of a dynamo and earth at the central station, and find it be 100 volts, we are absolutely certain that the fault, if it be a bad one, or the resultant fault, if it be a general one, is 100 volts from that + pole; and the question of finding where that fault is, is only a matter of adding the E.M.F. of the series of lamps from the + pole until the sum is 100 volts: the fault then is just after the last series. It is equally easy to ascertain whether the fault is a dangerous fault or not while the main current is flowing. By connecting the + pole through a high resistance to earth, and seeing whether the difference of potential is very much thereby reduced or not, the magnitude of the fault is at once indicated, and it is then a simple matter of calculation, knowing the reduction in the potential and the resistance inserted, to find the resistance of the fault. Thus by the electrometer method we have the way of finding the position of a fault and the magnitude of a fault in a circuit which is continually being charged with electricity, and by an electrometer I do not mean an expensive or elaborate instrument, such as is necessary with cable work;

Mr. Wright. when you are dealing with very high potentials it is not at all necessary to use anything more than a very simple electrometer. For instance, the attraction between two plates, one movable on an inclined plane to the other, forms a very practical electrometer. We have had such a one in use for the last three years, and it has proved of great value, showing at once where the fault is and its magnitude. In conclusion, I think that the most essential part of a high-potential system is maintaining high insulation, and the immediate remedy of a fault on its occurrence.

Mr. Varley. Mr. CROMWELL O. VARLEY: I presume that Mr. Bernstein's object in making his carbon hollow is to obtain a greater increment of radiating surface than of sectional area. When

$$\frac{(R^2 - X^2)\, w}{r^2\, w} = \frac{2\, R\, w\, L}{2\, r\, w\, l},$$

both have increased equally, and we have gained nothing. This formula gives us the minimum allowable value of X, which is $X = \sqrt{R^2 - R}$, taking r as our unit.

In practice the tube of carbon does not come out thin enough to meet these requirements; *i.e.*, light for light use two or three fine solid carbons in preference to one hollow carbon.

R = radius hollow carbon.
X = radius cavity in hollow carbon.
r = radius solid carbon.
L = length hollow carbon
l = length solid carbon
$\therefore L = l$.
w = 3·1416.

Mr. Evans. Mr. MORTIMER EVANS: I should like to make a further remark on the emission of light from highly reflecting surfaces, such as that of a polished mirror. In speaking upon this point at the last meeting, my remarks did not refer to grey carbon, as it has been called, or necessarily to carbon at all. The economy of light and the absence of heat emitted from an incandescent surface is, I hold, solely due to the reflective efficiency (if I may so term it) of the surface itself, and not in any way to the material of which it is composed. Were we able to produce a perfectly reflecting carbon surface, or, indeed, a perfectly reflecting

surface of any material capable of bearing the necessary temperature, I have little doubt but that an efficiency of 1½ or 2 watts per candle-power might be obtained, and this without any increase in the temperature or strain to the filament. We should also get a much cooler lamp. I am quite of opinion that the most of our lamps are run at too high a temperature; it would very often be greatly better, I think, to limit them to a maximum of, say, 200 candles per square inch, and certainly not incandesce or strain the filaments beyond that. I think, with Mr. Bernstein, that lamps should be worked more or less in series, though I would not go so far as he does, and have them wholly so. I would keep the E.M.F. moderate, and use lamps of 20 candle-power with a robust filament. I do not agree with speakers that there is no greater danger of collapse with a fine filament than with a thicker one; manifestly the advantage lies with the thicker filament. A flaw in a fine filament would most certainly reduce ts percentage of strength in a greater degree than a similar flaw in a thick filament. I doubt if there is any sufficient reason why lamps should not last an almost indefinite time if they are not over-incandesced—that is, if their temperature is not raised above the point at which disintegration of the carbon begins. It has been assumed that this disintegration occurs even at low temperatures, but I doubt if this is so. I suspect there is a certain critical point at which dissipation begins, and as the temperature and electrical pressure increase above this point, so will disintegration the more rapidly take place. I suggest it to be quite possible that a critical point exists which corresponds in some degree to limits of elasticity. If this is so, and if this critical point or elastic limit be not exceeded, disintegration may not occur at all. Mr. Evans.

Mr. Bernstein is right, I think, in his form of lamp—a point which has been rather called into question. I am satisfied it is a good plan to have the two terminals of the lamp opposed across its diameter, and if the critical point I have mentioned does exist it will probably be at its highest in the form of lamp Mr. Bernstein has proposed. I think lamps made this way should be placed horizontal, and held with a clip at the two ends. One

Mr. Evans. manifest advantage is, that you get a central and single terminal at each end, and are not cramped with two terminals dangerously near each other. The fact, also, of the two terminals being very far apart would, I think, very strongly tend to prevent the passage of the carbon molecules from terminal to terminal. The placing of the terminals so far apart is assuredly right, if all the other conditions can be made equal and convenient.

Mr. Swinburne. Mr. J. Swinburne: To a great extent I agree with Mr. Bernstein that low-resistance carbons, being stronger mechanically, are more durable than those of high-resistance. If lamps of 100 volts and 50 volts, of any makers, are both overrun on the same circuit at the same efficiency, the 100-volt lamps break first. Such tests as this are much more accurate than the vague reports we read of lives of lamps. But with lamps taking such currents as Mr. Bernstein's, difficulty arises from loss of heat in mounts and expense of proper exhaustion. Low-resistance lamps will often be found too hot to touch. Moreover, a thick solid filament is hotter in the centre; I presume that is why Mr. Bernstein uses a hollow filament—I mean tube (why not diaphragm ?).

I disagree with Mr. Evans, and entirely with Dr. Fleming, and, I think, with every other "lampist," about the best surface for carbons. Draper* roughly examined the radiation of heat and light from incandescent bodies, and found that all bodies at the same temperature are the same colour. The subject has since been more thoroughly investigated.† As colour is a test of temperature, the ratio of the light and heat radiated is constant for all forms of carbon at the same temperature. Thus, if a lamp of 20 candle-power and 50 volts at ·25 c.p.w. is needed, a carbon is made with certain surface and certain resistance. If the nature of the surface is now altered so that the carbon has a lower

---

* Memoirs, Becquerel's *La Lumière*.

† I have been asked for references, so I give a few from my index book:—Kirchhoff, "Ueber den Zusammenhang zwischen Emission & Absorption von Licht & Wärme," *Monatsbericht*, 1859, 783-787; "Ueber das Verhältniss zwischen dem Emissionsvermögen & dem Absorptionsvermögen der Körper für Wärme & Licht," *Pogg. Ann.*, cix., 1860, 275. Provostaye & Desains, *Comptes Rendus*, xxxviii., 977. Magnus, *Phil. Mag.*, s. 4, 39, 445. Möller, *Ann. Phys. Chem.* [2], 24, 266.

emissivity, and the lamp is still on 50 volts, it will give more than 20 candles and will be running at a higher efficiency, and on reducing the pressure till the lamp is again at ·25 c.p.w. it is no longer a 20-candle-power lamp. So that if the carbon is of low emissivity it must have more surface to give a given light at a given efficiency. I will most likely be understood to say that all carbons have the same emissivity. I think they have, very nearly, but I do not say so now; but what I say is that all carbons at the same efficiency are at the same temperature if the vacuum is the same. Even if I am quite wrong, the argument that a black surface is good because it has high heat emissivity would not hold; what would be wanted would be low heat emissivity and high light emissivity. Though, according to Tyndall, many of the views upon radiant heat commonly held by physicists are wrong, we have no reason to suppose black carbon is one of his exceptions. Either I misunderstand Dr. Fleming, or he has got his argument backwards. Similarly, I do not see that the roughness or smoothness of a carbon matters, unless it can be shown that the ordinary law of cosines does not here hold good. Mr. Swinburne.

The blue discharge at working efficiencies indicates a bad vacuum, though a bad vacuum may exist without it; and it probably in no way differs from an ordinary vacuum tube discharge. The lamps experimented upon by Mr. Preece were made on the other side of the Atlantic, where vacuums seem to be bad, which accounts for the phenomena being observed. There is, however, an invisible discharge even when a lamp is exhausted as far as possible. This suddenly increases on passing above a critical temperature, and as suddenly falls on reducing the efficiency.

Professor Thompson's remarks about self-induction in direct-current circuits seem a little misleading. There should be nothing for self-induction to correct, unless there are arc lamps; but if the dynamo tends to give an uneven current which is corrected by self-induction there is not only loss of power, but loss of available electro-motive force, so that the working capacity of the dynamo is reduced. The loss in alternating circuits might be lessened by using dynamos of long period and larger secondary generators. Helmholtz, in his "Sensations of Tone," gives

Mr. Swinburne. twenty-four vibrations per second as the least number unnoticed by the eye; we often use alternating currents of 500 per second.

There is no great difficulty in automatically maintaining a constant current. Mr. Wright has had an accurate governor working for a long time. Such a governor as the Thomson-Houston is not only too inaccurate for glow-lamp work—the lamps before us show a visible variation which is, of course, out of the question—but it demands a commutator of few sections, which means an intermittent electro-motive force controlled and largely wasted by self-induction, so that a larger dynamo is needed.

Mr. Mackenzie. Mr. Kenneth Mackenzie: Seeing Mr. Swan here this evening, it has occurred to me that at the end of 1880 (I think), in a lecture before the Literary and Philosophical Institution at Newcastle-on-Tyne, he described a system of running lamps entirely in series, the lamps being, of course, of a very different make to those now in use, and by which means he proposed to effect an economy in the wire.

There is one point about Mr. Bernstein's paper which requires careful attention. With 300 lamps running off one dynamo, if by any accident a lamp went out, *and the switch failed to act*, the remaining lamps would be put out, with no means of at once ascertaining which was the lamp which had gone, or where the fault was; consequently everybody would be left in darkness during the time, and there would be no means of finding out which was the lamp that had caused the accident, except by going round and turning each switch off and on till the right one was found.

Further, with a dynamo of 20,000 watts, the effect might be rather severe on the armature, and also on the gearing of the machine, if the whole load of 300 lamps were suddenly thrown off and on the machine by an accident of this nature, and serious damage might possibly be done.

One particular point has been left untouched by Mr. Bernstein, and that is, with regard to running lamps in series from secondary generators or transformers. However, I think he has hit upon what is the desideratum of electric lighting, for if we can get lamps of low potential and run them off secondary

generators in series, which secondary generators are themselves connected in series, I think we can attain to almost the acme of electric lighting, as the regulation of the current would be perfect in a *series* generator were we able to place the lamps also in series. This is due to the fact that in a series secondary generator the electro-motive force rises very considerably as the external resistance is increased—only, however, to a certain point. This is a matter I have been anxiously expecting to see accomplished, and if Mr. Bernstein can only satisfactorily solve the difficulty of low-potential lamps, and make them of even a still lower electro-motive force, say of 2 volts, it will, I am sure, be a great step forward in the right direction. Mr. Mackenzie

Mr. Henry M. Sayers: The system which Mr. Bernstein has described is very interesting to some of us who have been working at a similar system, and the difficulties which he has anticipated, and met in a very efficient way, are difficulties which we have experienced, and which at Brighton, Eastbourne, and other places, have been mostly overcome, though in different and sometimes rather makeshift ways. As to the difficulties of high-tension working, I am glad to be able, as the result of three years' working of high-tension systems, to assure the Society that these difficulties are much exaggerated. There is no insuperable difficulty or great danger in high-tension working. At Eastbourne, for nearly three and a half years, there have been two circuits running with 1,800 volts on them every evening, and during the whole of that time there has not been a single accident; no one has received a severe shock, either inside or outside the works, with the exception of myself. One evening I was making some experiments, and I managed to break the 1,800-volt circuit and put myself in the gap. I received no serious hurt, though knocked down. This result supports Professor Ayrton's remarks; but although 1,800 volts did not prove fatal, I do not wish to repeat the experiment. Mr. Sayers.

As has been remarked, the insulation of underground circuits is the most important point, and in practice has given me the most trouble. I do not know that anyone else in this country has had underground circuits with such an E.M.F. upon them for

Mr Sayers. so long a time. The insulation gave me a great deal of trouble at first, and I had to "dodge" the difficulties in many ways; and the result of my experience enables me to say that a five-mile circuit with 2,000 volts on it will, bar mechanical injury to the insulation, work perfectly for many years without repairs. Of course, as Mr. Wright has pointed out, the principal condition of maintaining such a circuit is the periodical testing of it, and his plan of testing while the current is running is well adapted to this system. Localising a fault on a high-tension circuit is a comparatively simple matter. You have all the best conditions for a loop test, and if the circuit has been carefully tested while being laid, a simple loop test, fairly well carried out, ought to enable the man in charge to put his finger on the fault almost instantly; and I can also say from experience that that is quite possible. Some speakers doubt the possibility of maintaining a constant current. I have not used any other than an ordinary Brush regulator, which works by automatically shunting the field magnets of the machine. By a little care in adjustment a Brush regulator can be made to keep the current (with very large variations of load) constant within one per cent. Of course there must be an alteration of current for the regulator to act, but the time during which the change takes place is very short, and groups of lamps can be switched on and off without producing any perceptible change in the other lamps on the circuit. There is another advantage in the series system which has not been noticed. As the load decreases and the lamps are turned off the speed of the machine can be reduced, so that no power need be wasted in keeping up a high speed for a small load, and it is not at all difficult to arrange that the same regulator which shunts the machine shall also alter the cut-off or throttle valve of the engine. The shunt action is of course a fine adjustment, the engine governor a coarse adjustment. That is a point of some little importance. I regret that time will not permit of my remarking on several other points.

Mr. Shoolbred. Mr. J. N. Shoolbred: May I beg to ask Mr. Bernstein if in his reply he can say something with regard to the financial question—as to the cost of the lamps? My reason for asking is

that I might possibly desire to use some of them in a way somewhat similar to the method referred to by Mr. Mackenzie. But as I fancy the price puts them out of the question (if I am correctly informed), I should like to have some data from Mr. Bernstein on the point. Mr. Shoolbred.

Mr. A. BERNSTEIN: Mr. President and gentlemen,—I desire, first of all, to express my thanks for the kindness with which you have received my paper, and my pleasure in finding that it has been the occasion of such an interesting discussion. If I am more grateful to one than to another for having taken part in this discussion, it will appear natural that I should be so to Mr. Swan, whose name is so intimately connected with the history of incandescent lamps. As I never had the pleasure of meeting Mr. Swan before, I gladly avail myself of this opportunity to express my admiration and personal regard for the perseverance and skill, which Mr. Swan has displayed in overcoming all those difficulties which the incandescent lamp must have offered in its early stages of manufacture. Mr. Bernstein.

In my reply to your remarks I shall follow out the same course I have pursued in my paper, and again speak first of the lamp itself, and then of the system of lighting.

Objection has been raised against the use of the word "strain" as indicating the relation between candle-power and number of watts required, and it has been mentioned that the word "efficiency" is already in use for this purpose. Although I am well aware that the last is the case, I do not think that the application of this word is an appropriate one. "Efficiency" of any apparatus is generally considered as a term which specifies an inherent quality of this apparatus—for instance in a dynamo, the relation between external and internal work; but the number of watts per candle-power in an incandescent lamp is an entirely arbitrary matter, not connected in any way with the construction of the lamp—as is, for instance, the case in an arc lamp—and merely affecting its life.

If we could combine the life, the light, and the power into one expression, the word "efficiency" might be well applied to it; but, as commonly used, the word is entirely misleading. A lamp

Mr. Bernstein. having a so-called high efficiency, according to the test of some authority, may in reality be a lamp of very inferior qualities.

In making comparative tests between glow lamps we have to note their behaviour and their length of life, when submitted to the same strain. In this respect the Committee of the Franklin Institute, to which we are much indebted for their meritorious work, seem to have made a mistake. The word "strain" may not be the best which can be found for the purpose, and I hope somebody will propose a better one. While I am speaking of measurements I may be allowed to add a few words in regard to the question, which has of late been much discussed, viz., the selection of a standard of light.

You will remember that in my paper I have described a lamp in which the expansion of the carbons, when raised to a high temperature, was indicated by the motion of a lever. If you consider that the light radiated by the carbon only depends on the surface and the temperature, then you will easily perceive that the lamp shown in Fig. 1 of my paper seems well suited for a standard. The indications of this lamp can always be reproduced under the same conditions, and they are free from circumstances which are not easily controlled. I do not think this lamp should be used as a commercial standard, for which purpose suitable glow lamps of ordinary construction might answer; but the standard, which I hereby propose, may be used as a normal, with which the commercial standards are to be compared from time to time.

Mr. Rawson has remarked that the deterioration of the carbons, of which I have spoken appears only to be due to the imperfect vacuum in the lamps, on which I have made my observations. I should say that just the contrary is more likely to be the case. If the vacuum is a very high one, such as Professor Crookes used in his famous experiments, then the action of throwing off carbon from the negative side and the consequent gradual deterioration of the high-resistance lamp, takes place. In fact, it might appear questionable whether it would not be advisable to produce such a state of atmosphere inside such lamps, by the introduction of an inert gas, that the lamp can no longer be

considered as a Geissler tube, if, on the other hand, the economy of the lamp would not be greatly decreased by these means. I must further differ with Dr. Fleming, who wants us to believe that the deterioration is merely the effect of heat. The very interesting observations which Dr. Fleming himself published some time ago contradict his statement. If only destruction produced by heat takes place, then the disintegration ought to extend in an even manner over the whole carbon, and the deposit should be evenly distributed over the inside of the bulb. We all know that this is not the case, and it seems to me that the explanation which I have given in my paper, attributing the deterioration in high-resistance lamps to a combined effect of heat and electricity, is more likely to be correct. Mr. Bernstein.

Dr. Fleming has called attention to the importance of homogeneity in the structure of the carbon, and here I fully agree with him. The thicker carbon is only then the more durable if it has the same homogeneity in structure as the thin carbon; otherwise it is likely to be destroyed much sooner. It is just here where the hollow carbon has, for obvious reasons, shown itself of enormous practical advantage.

Mr. Rawson has expressed the opinion that the carbons in the Bernstein lamp, which he had formerly seen, had not a very high emissivity, as he calls it; and he thinks the carbons now used may be better.

I hope they are better; but I should like to know how Mr. Rawson estimated the carbon as regards its power of emitting light and heat. I have often desired to make experiments upon this point, but there are enormous difficulties in the way, and opinions upon this question seem to differ very much. Mr. Mortimer Evans, Dr. Fleming, and Mr. Swinburne have each expressed a different view. As for myself, I must confess that I think it very well possible that the proportion of light and heat emitted at higher temperatures may differ with the nature of the substance and of its surface; but this is merely an impression, and not a conviction substantiated by facts. Mr. Evans lays great stress on the smooth surface of the radiating body. I think he is quite right to do so, but the advantage of the smooth

Mr. Bernstein. surface may be at the same time in a direction different from the one which he indicates. I have lately made low-resistance lamps —and in these lamps we have only to deal with the effects of heat, as the electric forces may be considered as nil—the carbons of which had a surface as smooth as a mirror, and I noticed that such carbons will withstand a much higher temperature without any evaporation than carbons with a rougher surface.

I cannot understand Mr. Crompton's objections to the explanation of the blue flame which I have given. Platinum absorbs very small quantities of hydrogen, but condenses enormous quantities of oxygen—a fact which is utilised to a great extent in practical chemistry. Further, the blue flame on the positive platinum *is* a flame, and has nothing in common with fluorescence, which is a property of a certain class of substances, to which platinum certainly does not belong.

In reply to the question of Major-General Webber, I think that I have to correct one of the statements in my paper. I spoke of the platinum wire as being surrounded by the proper kind of *glass*, but I should have said that the sides are embedded in a special kind of *enamel*, which has the quality of adhering well to the platinum, and welding together with ordinary glass.

If the receiver is made entirely of glass, it is quite impossible to use large currents in the lamps; but by making that part of it through which the wires pass of enamel, this difficulty is overcome. The construction of the lamp, as far as the glass part is concerned, is the same as that of the ordinary Geissler tube.

I shall now turn to those remarks which have been made respecting the second part of my paper.

Mr. Mordey has called attention to the fact that hitherto glow lamps have been found to last longer when worked in parallel than when in series, and Mr. Mordey has at the same time given the true explanation of this fact. Lamps, which increase in resistance, will gradually give less light with the same power when put in parallel, but they will thereby prolong their life. The reverse takes place if these same lamps are placed in series: they will then gradually give more light, and, as the strain upon them is increased, their life will be shortened.

To give an example of the behaviour of a well-known high-resistance lamp in this respect, I quote from the results of the Committee of the Franklin Institute the behaviour of the Edison lamp No. 1. Mr. Bernstein.

The lamp requires in the beginning of the experiment 98·9 volts and ·69 ampère, giving a light of 15·3 candles, and it therefore requires 4·5 watts per candle.

After about 1,000 hours, the candle-power has gone down to 7, and the power now absorbed is 8·7 watts per candle, or almost twice as much as in the beginning.

This example will sufficiently demonstrate the importance of using, for the parallel as well as for the series system, lamps which will not alter.

I hope very shortly to publish figures which will show the behaviour of the low-resistance lamp in that respect, and I shall therefore abstain from making any further remarks upon that point at present.

I cannot agree equally well with Mr. Mordey in his recommendation of a system, in which a series of lamps placed in parallel is used. I think this arrangement can never be as satisfactory as a simple series system, and in a general system for the supply of electric light the independence of every lamp must be considered as a *conditio sine qua non.* This does not exclude an arrangement by which several lamps may be turned on and off from a single switch in special cases.

One of the points in my paper, which seems to have elicited considerable comment, is the action of the cut-out, and the fear of an interruption of the circuit if such a cut-out should fail to act. As these cut-outs generally consist of an electro-magnet, which is placed in a shunt, and as the magnet has a very large margin of current to act in, I do not see why the same should not act. A magnet is as sure to attract as the earth. The failure of telegraph instruments in this respect does not result from the failure of the magnets in their action, but from entirely different causes. I have used similar cut-outs for more than two years, and have never known one to fail.

But in order to satisfy those who are afraid of relying on the

Mr. Bernstein.

cut-out, I have lately added an arrangement which makes the interruption of the circuit a physical impossibility. For this purpose the wires which lead to the shunt coil are made sufficiently thick to carry the current of 10 ampères, and the coil is enclosed in asbestos paper. If the lamp gives out and the cut-out does not act, then the current in the shunt will gradually increase; the thin wire becomes heated, and the silk insulation carbonises. The consequence is that by-and-by the shunt coil of high resistance transforms itself into a short conductor of large cross section, which can carry the whole current. I have made the experiment several times, and always with the same result. It produces a disagreeable smell and smoke, but it is entirely devoid of danger; it should never happen, and, if it does happen, can be stopped at once by the motion of the switch lever.

For additional safety there is an automatic cut-out connected with every house switch, so that the interruption of the current in one house by the cutting of a wire could not affect the other houses in the same circuit.

For large public buildings such as, for instance, the British Museum, I would propose to supply the same by several circuits, of each of which only a small part of its total E.M.F. is used in the building.

There is hardly any limit to the number of safety arrangements which may be used, although I feel convinced that they will prove superfluous.

A great deal has been said about the uncertainty of electric light, but this uncertainty has been merely the consequence of the small scale on which electric light plants were formerly made. The larger the scale the greater the certainty in the supply; and if electric plant is made only nearly as large as gas plant is usually made, then people will find that they can depend upon the supply of electric light just as confidently as on the supply of gas.

Before proceeding any further, I wish to make an experiment in order to demonstrate the action of the cut-out. For this purpose I shall now include a lamp with no vacuum in the circuit by moving the switch lever [*does so; the light of the lamp*

increases until the carbon breaks, when the cut-out acted and prevented any effect upon the other lamps]. Mr. Bernstein.

Here I may now answer a question of Mr. Rawson, who could not understand how incandescent lamps in series can be put in and taken out without danger when the current is passing through the circuit; but he quite forgets that by turning the switch lever into position 1 [*does so*] I am disconnecting the wires leading to the lamp from the main line. Although there is a current of high potential passing through the main line, I can now take away the broken lamp, take hold of the bare ends of the wires with my hands [*does so*], and put in a new lamp without the possibility of coming into contact with the current. The system must therefore be considered absolutely safe in this respect, even if the main line should suffer from defective insulation.

I now turn to the last point upon which I shall have to say a few words, viz., the application of high-tension currents. I was very pleased to notice that some of the highest authorities in electric lighting in England have come to the conclusion that there has been much unjustifiable prejudice against the application of such currents.

The Board of Trade has at present fixed 200 volts as a limit of difference of potential which should be used inside a house. The idea of such limitation can only be that people may with impunity take hold of two bare conductors which have this difference of potential between them. But if 200 volts are the limits of safety for full-grown men, then they must certainly be considered quite unsafe for children; and these require our protection more than grown-up people. In fact, I would hardly undertake to say where the limit of safety would be under such circumstances. I have myself witnessed a case in which a strong man was knocked down by a current the E.M.F. of which could at no time exceed 50 volts. The effect upon him was evidently produced by a sudden change in the E.M.F. of the dynamo. Professor Ayrton has already called attention to the fact that not the E.M.F., but the constancy of the current, seems to be the main point as regards safety.

Mr. Bernstein.

The determination of 200 volts as a limit was made in 1882, when we had but little experience in electric lighting, and the idea of fixing the limits of the E.M.F. was evidently derived from laboratory experiments, in which we are in the habit of handling bare terminals. But the conditions of actual lighting are very different from those of laboratory experiments. We have now four years' more experience behind us for our guidance; and looking towards the United States, where electric light occupies a far larger field than in England, we find that several thousands of circuits with high E.M.F. have been in operation for years. We have heard of accidents to attendants, which accidents might have been easily prevented by proper care, but we have never heard of any injury to those using the electric light, although it is applied in shops, warehouses, and a great many other inhabited buildings. This fact speaks very strongly in favour of high-tension currents.

It may be asked what precautions should be adopted in case we make no limitation as regards the E.M.F. I think I have indicated the answer already in my paper. There are two conditions which should be fulfilled—firstly, the whole plant inside a house should be constructed in such a manner, that no one can come in contact with any part conveying a current; in the second place, the electric light company, which supplies the current must be made responsible for the maintenance of a certain insulation resistance.

If these two conditions are complied with, electric light will be far safer than any other illuminant, whatever the E.M.F. of the current may be. As to the maximum E.M.F. of which we can avail ourselves, that will regulate itself according to the means of insulation which we may possess.

The PRESIDENT: Will Mr. Wharton kindly state the conditions of the experiments which it is intended to show with the lamps before us?

Mr. Wharton.

Mr. WHARTON: I do not know that there is anything to explain. The few arc lamps before you, as well as two outside, are in series with the incandescent lamps, and can be switched in and out without interfering with them. The dynamo is not

showing to its best advantage owing to the damage it sustained, and to which I have before referred, but I will run a sufficient number of arc lamps to make an illustration. [*Two arc lamps were turned off, leaving the nine glow lamps and three arcs running; afterwards the remaining three arc lamps were successively turned out while the glow lamps continued to run, and the only effect was a very momentary increased light from them.*] Mr. Wharton.

The President: Gentlemen,—I have very few words to say at this late hour, but I am sure that we all ought to be grateful to Mr. Bernstein for his remarkable paper—remarkable for the simplicity with which he has put forward important facts. We have had an admirable discussion and an admirable reply, and I ask you to accord a vote of thanks to Mr. Bernstein for his paper, and also to Mr. Wharton for the interesting installation he has shown us to-night. The President.

The motion was carried unanimously.

A ballot took place, and Mr. A. C. F. Webb was elected a student, after which the meeting adjourned.

THE LIBRARY.

ACCESSIONS TO THE LIBRARY FROM MARCH 20 TO MAY 1, 1886.

By Alfred J. Frost, *Librarian.*

(*Works marked thus* (*) *have been purchased.*)

IT IS PARTICULARLY DESIRABLE THAT MEMBERS SHOULD FORWARD COPIES OF THEIR WORKS TO THE LIBRARY AS SOON AS POSSIBLE AFTER PUBLICATION.

* **Anon.** "Unicode:" The Universal Telegraphic Phrase-Book. A code of cypher words for commercial, domestic, and familiar phrases in ordinary use in Inland and Foreign Telegrams. 8vo. 103 pp. *London*, 1886

Berge. [*Vide* Schulze-Berge.]

Franklin Institute. International Electrical Exhibition of the Franklin Institute, 1884. Report of the Examiners of Section XXII. (Section IVa., Classes 5, 6, 7.) Supplementary Report on Meteorological and other Registers. 8vo. 13 pp. *Philadelphia*, 1886

—— International Electrical Exhibition of the Franklin Institute, 1884. Report of the Examiners of Section XXIX. (Section VIII., Class 1)—Educational Apparatus; with which is incorporated Section XIII.—Apparatus for High Electro-motive Force. 8vo. 56 pp. *Philadelphia*, 1886

Institution of Civil Engineers. Minutes of Proceedings. Vol. LXXXIII. 8vo. 582 pp. Plates. *London*, 1886

Ordnance Department, U.S.A. Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year ended June 30, 1885. 8vo. 689 pp. Plates. *Washington*, 1885 [By Exchange.]

Philosophical Society of Washington [Bulletin of.] Vol. VIII. Containing the Minutes of the Society and of the Mathematical Section for the year 1885. 8vo. xlvii. + 68 pp. *Washington*, 1885 [Exchange.]

Rodary [F.] Applications de l'Électricité aux Chemins de Fer cours professé à l'école supérieure de Télégraphie. 8vo. 104 pp. *Paris*, 1886

Royal Observatory, Greenwich. Diagrams representing the Diurnal Change in Magnitude and Direction of the Magnetic Forces in the Horizontal Plane at the Royal Observatory, Greenwich, for each month of the several years 1841 to 1876. Appendix to the "Greenwich Observations, 1884." 4to. 11 pp., xxxvi. Plates. *London*, 1884

Schulze-Berge [Franz]. Ueber die Elektricitätserregung beim contact von Metallen und Gasen. 8vo. 38 pp. Plate. [Inaugural-Dissertation zur erlangung der Doctorwürde von der Philosophischen Facultät der Friedrich-Wilhelms Universität zu Berlin, 5 Nov., 1880.] *Berlin*, 1880

* **Tamine** [René]. Recherches Théoriques et Pratiques sur les Accumulateurs Électriques. 8vo. 333 pp. *Mons*, 1885

Treuenfeld [R. von Fischer]. Militär-Telegraphie. La. 8vo. 17 pp. Plate. [Separat-Abdruck aus der *Zeitschrift für Elektrotechnik*. Heft III., 1886.] *Wien*, 1886

—— Die Militär-Telegraphie in Spanien. 4to. 16 pp. [Separat-Abdruck aus der *Elektrotechnischen Zeitschrift*. 1886, Januar.] *Berlin*, 1886

ORIGINAL COMMUNICATIONS.

DELANY'S SYSTEM OF SYNCHRONOUS MULTIPLEX TELEGRAPHY.

1. Delany's system is based upon two main principles—first, that of synchronism, or the simultaneous motion of similar pieces of apparatus at two different places; and, secondly, that of distributing to several telegraphists the use of a wire for very short equal periods of time, so that practically each telegraphist has the line to himself during these periods.

The combination of these principles of working was introduced by Meyer in 1873; it was improved upon by Baudot in 1881; synchronism was perfected by Delany in 1882, and the system completed in 1884.

2. As Delany's system differs very markedly from what are known as the "duplex" and "quadruplex" systems, it is proposed, for clearer definition, to give to the modes of working his system names based on the Greek word *hodos*, a way.

Thus a two-way mode of working, or a mode by which two messages are practically sent at the same time, will be *diode* working, three-way *triode*, four-way *tetrode*, five-way *penthode*, and-six way *hexode*.

"Duplex" and "quadruplex" are such well-rooted and explicit terms defining particular modes of working by compensation, that their application to different modes of working based on a different idea may lead to confusion, while new and distinct terms will confine the attention to the new and distinct system.

3. A and B are two separate offices connected together by a line wire L.

Fig. 1.

If the arms a and a', in electrical connection with the line wire L at A and B, rotate simultaneously around the circles 1, 2,

3, 4, in the direction of the arrows, making contact upon the segments as they pass, then when a is at A1 a' will be at B1, when a is at A2 a' will be at B2, and similarly for 3 and 4.

If 1, 2, 3, and 4 at each office be each in connection with a set of similar telegraphic apparatus, the four sets at one office will be in direct communication with the four sets at the other office as the arms a, a', touch their corresponding segments. Thus for each rotation of the arms the instruments at A1 and B1 will be in direct communication with each other *once;* and so on with those at A2 and B2, &c.

4. If each segment be divided into four segments, and by means of these be connected with the four instruments instead of with only one of them, then during one complete rotation each

Fig. 2.

arm will place corresponding instruments in communication with each other *four* times. Or if each circle be divided into 40 segments, and each of these 40 into four segments, then corresponding instruments will be in communication with each other *forty* times during each complete rotation of the arms a and a'.

In Delany's apparatus there are 84 segments in the whole circle, and these are grouped differently according to the number of ways of working. Hexode working requires one grouping, triode another, diode another, and so on.

5. Two tuning forks pitched to absolutely the same note, and set in vibration by currents like an electric trembling bell, will move in synchronism, but the synchronism cannot be maintained. The deposition of dirt, dust, or moisture, changes of temperature, variation of current, produce changes which affect the rate of motion.

Paul la Cour, of Copenhagen, invented an ingenious way to maintain the synchronism.

Fig. 3.

F is a tuning fork vibrating between the poles of magnet M_1. There are two contact points (c, c'). At c is completed a circuit containing the battery B and an electro-magnet M. The other contact (c') completes the circuit containing the battery B_1 and the electro-magnet M_1.

Every time the tuning fork touches the contact point *c* a current is sent through the electro-magnet M, which therefore is magnetised once for every excursion to and fro of the fork. In front of the magnet M there is a wheel W, whose teeth are of iron, and every time the magnet M is excited attraction is momentarily exerted on the nearest tooth. If the tooth is approaching the pole it is urged forward, if it is moving away from the pole it is retarded. Hence the wheel is propelled with wonderful uniformity and with considerable force. The electro-magnet M_1 is similarly excited, and it maintains the fork in constant vibration. This "phonic wheel," as it is called, Delany uses in connection with a "distributor;" but he has adopted a reed instead of a tuning fork.

6. The "distributor," as arranged for hexode working, is shown by

Fig. 4.

The circle is divided into six groups, each group having 12 platina-faced brass segments insulated from each other, and being separated from the next group by what are called the two correcting segments, one (shaded) called "dead," and the other (clear, and marked B or C) called "live." The segments are not only insulated from each other, but are separated by the spokes of the brass rim A, which is connected with earth. Each group of 12 segments is further subdivided into two sub-groups of six, in which the corresponding segments are connected, so that 1 and 1, 2 and 2, 3 and 3, and so on, are electrically joined together. Not only so, but they are connected to every corresponding number in the other groups around the circle. In Fig. 4 the segments in only two of the sub-groups are numbered, but the remaining 10 sub-groups must be understood to be all numbered in the same way. The twelve segments numbered 1 are electrically connected to the telegraphic instrument numbered 1; the twelve segments numbered 2 are connected to the instrument numbered 2; and so on. The first, third, and fifth "live" segments are connected together, as also are the second, fourth, and sixth; but the first three are intended to *receive* currents from the distant station, while the second three are connected to a battery B,

and so can *send* currents to the distant station. The "dead" segments are so arranged that one is fixed *before* each receiving "live" segment, and one after each sending "live" segment.

The correcting segments are connected in the manner described for lines whose inductive capacity is small, and where the retardative effect on the current is consequently slight; but when the capacity is considerable, the segments which are called "dead" are brought into use; the sending correcting battery is then connected to the "dead" segments immediately in front of the broad segments, and the receiving correcting relay is connected to the "dead" segments immediately following the segments shown in the figure as "live" B segments. This arrangement gives a space of one segment to allow for retardation of the current when the capacity of the line exceeds three microfarads. When, however, the capacity is within that amount, this space is not required; indeed, it would be disadvantageous, because there is very slight loss of time in the transmission of the signal. The receiving correcting segment is therefore extended in such a manner as to meet the trailer, and so receive the correction almost as soon as it is sent. It is not really necessary that the segment should be made broad, but only that it should be moved in the direction indicated; it is only made broad to fill up the space.

The arm or trailer T passes lightly on the surface, and moves continuously round the circle, coming successively in contact with every segment. It moves in the opposite direction to that of the hands of a watch. It is electrically connected to the line wire L. In every rotation, it makes 84 electrical contacts, 72 of which are for telegraphing, while the others are for maintaining synchronism.

The function of the trailer is to place the line wire successively in connection with the segments in the different groups. The currents of electricity that flow through the line wire are dependent upon the operations performed upon the telegraphic apparatus, and they are broken up into short rapid pulsations or impulses by the momentary contacts made by the trailer.

The uniform rotation of the trailer is produced by La Cour's wheel, shown in Fig. 3.

Fig. 5.

7. Fig. 5 shows the La Cour wheel in connection with Delany's actuating, correcting, and synchronising devices. The iron-toothed wheel A is placed before the poles of the electro-magnet D, which is magnetised periodically and regularly by currents from the battery B'_2 sent at each vibration of the reed E' at H'. It propels with great uniformity the toothed wheel, to the axle of which is attached the trailer T.

The impulse must be given when the tooth is at c, and cease when it is at c', Fig. 6.

Fig. 6.

Momentum takes it on until the next tooth comes to c, when the next impulse is given. The impulse must last while the tooth moves from c to c'. If it continued beyond that time it would check the motion of the tooth. As the impulses are due to the vibrations of the reed, the motion of the wheel must follow exactly the vibrations of the reed.

Resistances (r_2 and r_3, Fig. 5) are placed as shunts around each of the contacts H and H' to prevent sparking.

The vibrations of the reed are maintained by the electro-magnet F' excited by the battery B'_3 every time contact is made at H.

The end of the reed E' vibrates between the extended pole pieces of the electro-magnet M'_1, and thus it vibrates in a magnetic field. This magnet is excited by the battery B'_4 whenever contact is broken at K', and this contact at K' is broken whenever the current from battery B'_5 ceases to flow in M'_2. This depends on the action of the relay R', which is excited by currents received from the distant station coming through the "live" correcting segments of the "distributor" there, and which, therefore, when its armature is attracted, breaks the local current flowing through M'_2. When the magnet M'_1 is excited the magnetic field in which the iron reed vibrates tends to retard its rate of vibration by attraction, so that if it vibrates too frequently its rate is checked. The normal rate of vibration

may be adjusted by a sliding weight, or in various other ways not shown in the figure.

8. The mode in which each set of apparatus is connected up is shown by Fig. 7.

Fig. 7.

A portion of one group of segments of the "distributor" at each station is indicated, and the trailers are shown to be in contact with corresponding segments which direct the current to the telegraphic apparatus. There is nothing peculiar in the telegraphic apparatus (the usual Morse sounder set), except the relay R, which by its form is rendered sluggish, so that the sharp rapid currents collected by the trailer are practically made continuous in their action on the armature of the relay. The currents flowing through the line wire are short, sharp, rapid impulses or waves of electricity, and to convert these waves into telegraphic symbols, such as Morse characters, some mode is needed to render them continuous for the duration of a dot or a dash. The relay has a condenser (C, Fig. 8), and

Fig. 8.

a permanent horse-shoe magnet (NS) fixed below the coils. The cores are thus polarised. The result is that the self-induction of the coils, adjusted by the condenser, retards the demagnetisation of the core, so that the effect of the rapid succession of short currents is made continuous upon the armature of the relay, and the marks are made as though they were produced by continuous currents. Dots and dashes are thus recorded without breaks.

The relay R, Fig. 7, actuates an uprighting relay M, which in turn actuates the sounder S. This arrangement is introduced because the ordinary method of completing the local circuit is too slow and the contacts are not firm enough. It has been mentioned that each segment is separated by an earth contact—a spoke of the brass rim. This is done to favour the rapid discharge of the static charge to earth between each electrical impulse or current.

The apparatus being ready, six pairs of corresponding telegraphists are placed in communication, and each pair has virtually a circuit to itself.

It will be observed that in Fig. 5 only the correcting "live" and "dead" segments are shown. Of the "live" segments, those in connection with the battery are of the usual dimensions, while those in connection with the reed correcting apparatus are broad. This is to admit of corrections being made *before* the working segments are affected. Want of synchronism is thus prevented.

When the trailer at station A is on the narrow segment, that at station B is on or near the broad segment. If the wheels are in perfect synchronism, the trailer at B is on the "dead" segment; when at A it is on the sending "live" one, and *vice versâ*; hence no current flows; but when the wheel at B is in the least degree in advance of that at A, then the trailer at B is on the receiving "live" segment, a current flows, it excites relay R′, the electro-magnet M'_2 is also excited, the magnetic field is formed, and the vibration of the reed E′ is retarded. Perfect synchronism is again obtained, and the correcting currents cease to flow. Six correcting currents can be sent at each revolution, three in one direction and three in the other. Thus a deviation of a thousandth of an inch can be speedily rectified.

This method of Mr. Delany is perfectly automatic in its action, and it maintains synchronism to an extent that has never before been known. Attempts have been made to synchronise by sending correcting currents in one direction and applying the corrections mechanically to moving parts. Baudot brings to bear a friction break by such means, but it has not been successful in practice, whereas Delany's method is practical and successful.

The "distributor" rotates nearly three times in one second, hence 252 contacts are made each second in hexode working. The distance to which the system can be worked hexode is limited, for owing to the retarding effect of static induction the number of currents which can be sent per second is limited by the static capacity of the line. Now, as the static capacity of the line has the effect of retarding the speed of the current, it follows that the limit of working is dependent on the magnitude of the static capacity, for if the current be late, it will enter the wrong segments, and confusion of signals will result.

The retarding effect of static capacity can be met by making each group of a greater number of segments, or by making the segments of greater breadth, but this has the effect of reducing the number of ways of working. Either plan would reduce the hexode to tetrode or triode working.

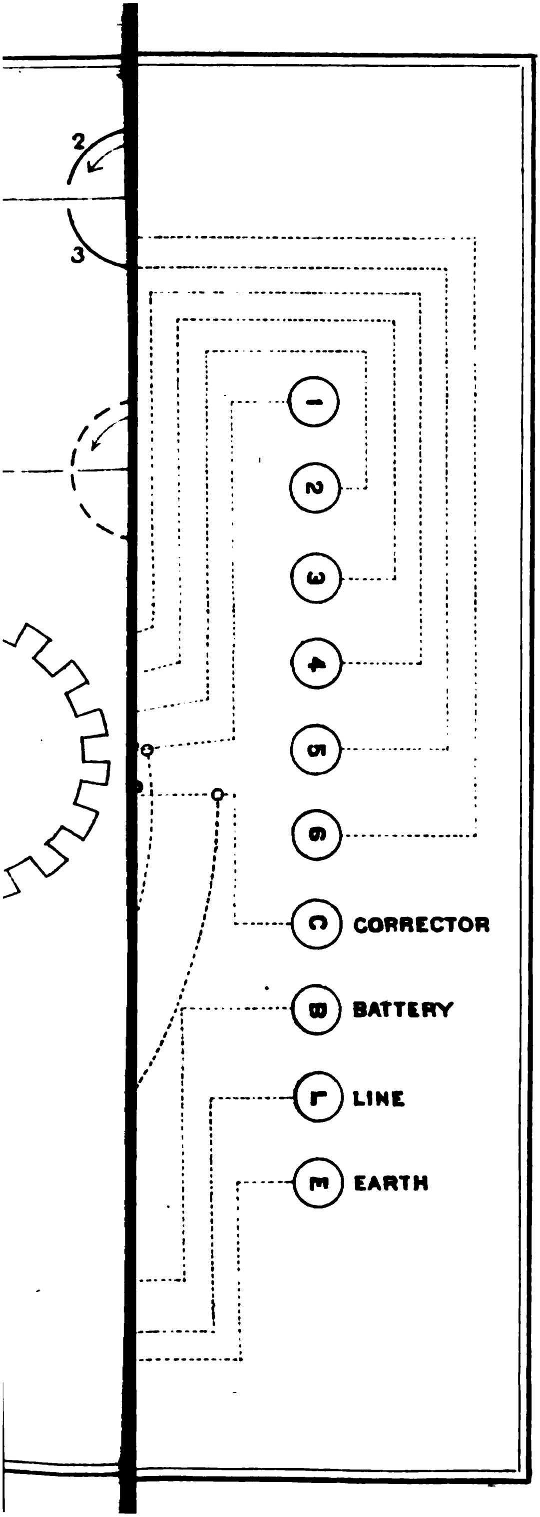
So far, it should be understood, the system has been described as one for working in either direction (not simultaneously, as in duplex, but alternately), as in ordinary simplex working. If, however, it be regarded as a system for working in one direction, distance has not the same effect upon it.

If static capacity only so reduces the speed of the current that while it leaves segments 1 at station A it enters segments 2 at station B, then it is possible still to work five ways *in one direction*, for every other segment will be advanced one. For this mode of working two wires are necessary, one for sending and the other for receiving, but it has this advantage, that two wires can be converted into ten circuits. Segment 6 is rendered useless in consequence of its currents arriving at B when the trailer is on the correcting segments. Working in either direction, hexode is feasible between London and Brighton, but tetrode is the limit to Bristol and Manchester. In one direction, however, to Bristol and Manchester, even six circuits have been operated, so that with two wires 12 circuits might be worked, six in each direction.

The great advantage of the system is that it does not disturb the general mode of working adopted in this country. The sounder system is retained. Key working is maintained. All initial delay due to punching is avoided. The skill of able telegraphists is fully utilised. Each telegraphist has an independent circuit, so that he has not to wait for a lagging co-operator as in quadruplex. When there is a rush of traffic in one direction the system can be worked all in one direction, and not only half of it as in the quadruplex. The system, moreover, is only in its infancy, and there is little doubt that further experience will lead to its being improved.

W. H. PREECE.

January, 1886.


2
3
1
2
3
4
5
6
C CORRECTOR
B BATTERY
L LINE
E EARTH

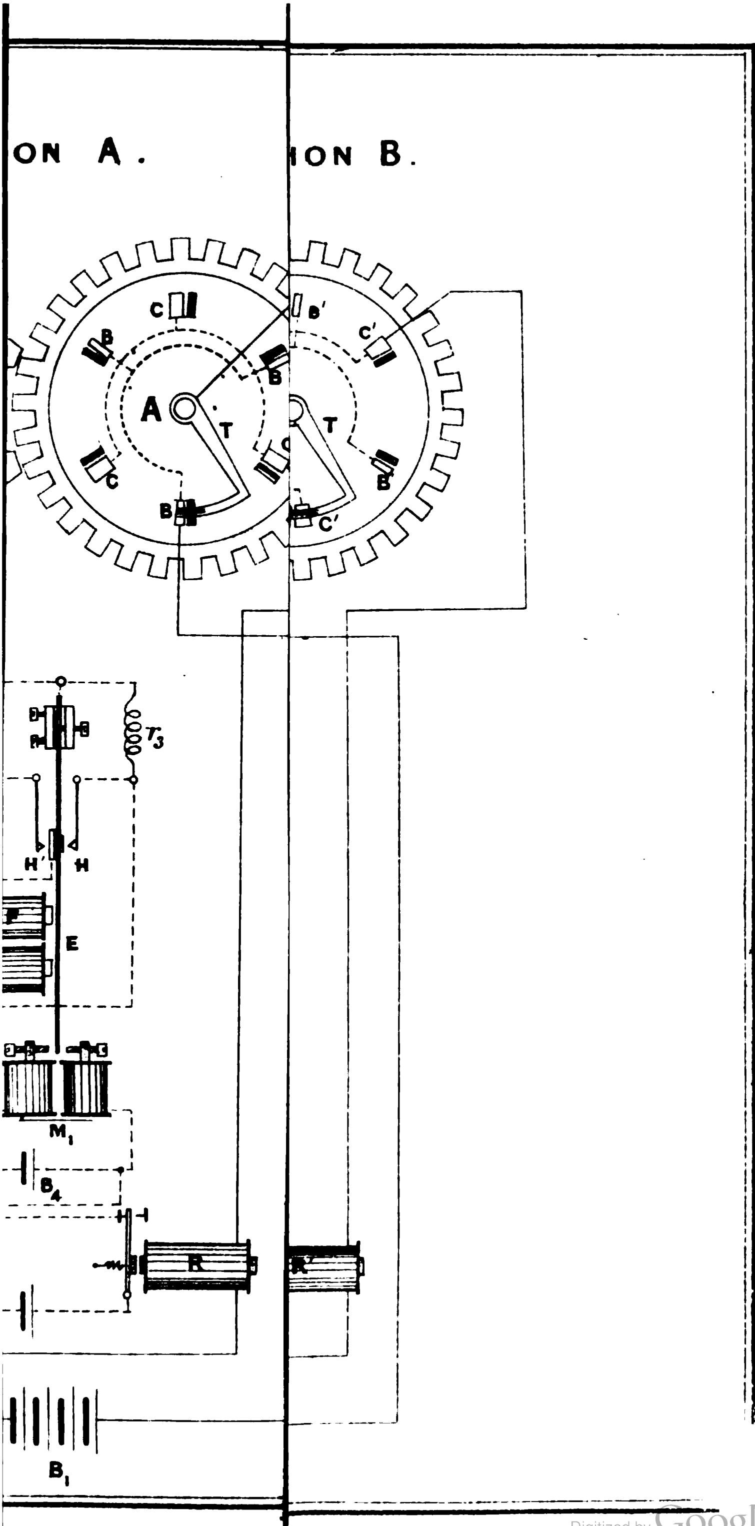
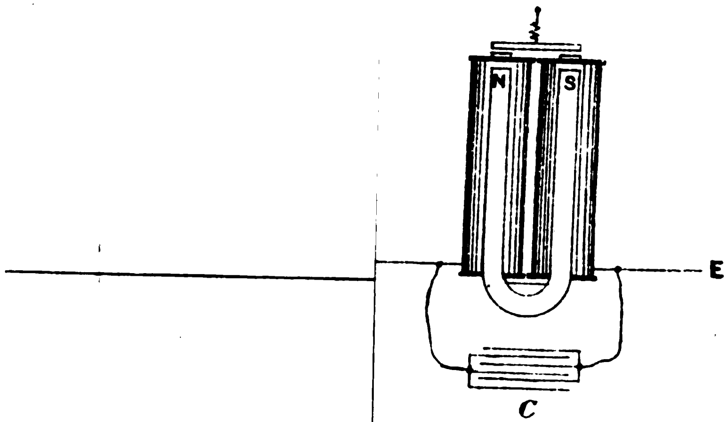

ON A.
ON B.
C
B
B
A
T
C
B
B'
C'
T
B
C'
T3
H'
H
E
M1
B4
R
R'
B1

FIG 8.



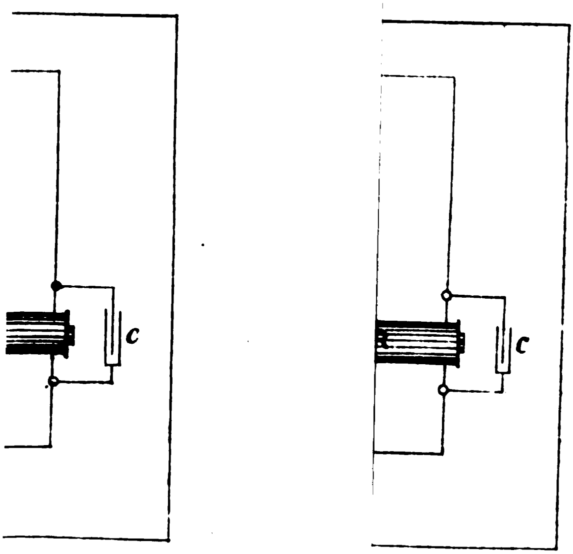
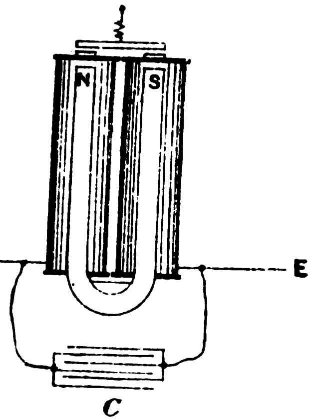
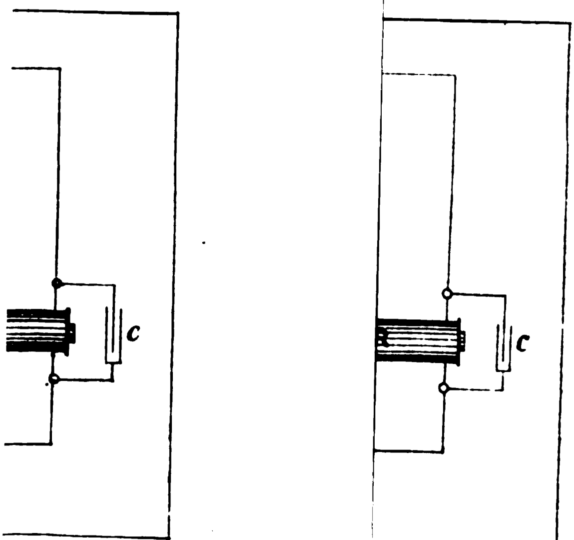


FIG 8.





THE RELATION OF ELECTRIC LIGHTING TO INSURANCE.

By C. J. H. Woodbury, Boston, Mass.

The numerous and continuous injuries to persons and to property, in spite of all precautions, have caused the most stringent statute laws relative to the production of artificial light. Although differing in the several States, all relate to similar measures.

This class of laws has been a necessity in the endeavour to reduce the casualties resulting from the use of artificial light; and, wide as they are in scope and exact in details of enforcement, the painful consequences following the use of oil and gas show that these laws fall short of their purpose.

At this time we have occasion to consider only one of the several methods of illumination, and it is remarkable that electric lighting, which is in general use throughout the country, and containing, like all other forms of energy, well-known possibilities of danger, has never been the subject of any State law yet in force.

City ordinances have been passed for a purpose, and to no purpose. The questions of the safety of electrical illumination have thus far been settled by the electric interests without intervention of the law; and I venture to state that the instance of an industry voluntarily assuming its self-government for the direct weal of other interests is without parallel. When electricity was first applied for illumination on a commercial scale, it was a business without precedents: everything was new, crude and undeveloped. The development of the whole business required invention, education and organisation from one end to the other.

Considering the nature of the difficulties which were surmounted, the wonder is not at the mistakes, but at the success.

One of the elements naturally disregarded at the outset, in the rush to invent, make and install the apparatus, was the possibility that electricity might, like other methods of lighting, become a cause of fire.

Soon, numerous fires served as a reminder that electricity, as applied at that time, possessed no immunity from consequences

similar to those resulting from other methods of illumination, and public opinion for a time had a tendency to veer to an extreme position—even farther from the truth than its first assumption that electricity could not produce a fire.

A careful examination of the circumstances attending a number of these fires, and a repetition of these conditions upon electric lighting plants, served as the basis of the regulations for the use of electric lighting apparatus prepared by the writer, a little more than four years ago, for the Factory Mutual Insurance Companies. It would have been impossible for the work to have been carried on had I not received the most cordial co-operation from the Electric Light Companies; and the electricians at the head of these Companies freely gave of their experience, in the endeavour to determine the facts at issue.

The results of this work warranted the opinion that a well-arranged electric-lighting plant was the safest method of illumination, and the experience of time has sustained that position.

The essentials for safety in an electric-lighting plant are few and simple. In the presence of combustible material, arc lights should be enclosed in globes resting on closed stands with a raised edge, confining the sparks and copper, and some extra stop at the bottom of the lamp to prevent, in any contingency, the lower carbon from falling. The feeding apparatus at the lamp should prevent the formation of an undue arc in case of any disarrangement. Switches should be constructed so that an arc could not be formed by their use. The electricity must be confined to its metallic circuits and the conditions of its use controlled.

The regulations found necessary to specify these particulars in detail are of some length, but do not embody any other features. Experience has shown that they have served the purpose for which they were intended, for I do not know of any fire from electric lighting apparatus except where they have been violated.

The chief elements of danger are conductors of high resistance, generally formed by two earth contacts, and sometimes by a conductor between two wires of different potential. Such diver-

sions of current are generally caused by water penetrating the insulation, and it is of importance that the insulation be waterproof, wherever there is liability of exposure to moisture.

The enforcement of these rules by the Factory Mutual Insurance Companies and the Boston Fire Underwriters' Union was based upon an inspection which was recorded upon printed forms prepared for specifying in detail the nature and position of the dynamo and of the conductors, and the results of tests for insulation, &c.; the nature and situation of cut-outs, switches, and other accessories; the number and nature of arc and incandescent lamps, &c.; with space for such additional remarks as the inspectors, who are required to date and sign the forms, might deem necessary.

For inspection use, these forms are secured by rubber bands in a small portfolio the size of a pocket note-book, and after a record of them has been made they are filed away at the office.

Careful attention should be given to the importance of daily tests for ground connections, and for this purpose an ordinary Bell magneto is the most convenient apparatus. The electric bells and small galvanometers, with low-resistance coils frequently used for this purpose, are not sufficiently delicate, as they cannot indicate a weakness in the insulation, unless its resistance be less than ten to one hundred ohms, according to circumstances.

The general average of electric plant installations have no place for the expensive apparatus and methods necessary to measure the resistance of the insulation of the system. Whatever method may be employed for permanent testing, the line connecting the electric light circuit with the testing apparatus and thence to the earth should have a spring switch which could not be left closed, and thereby ground the circuit.

I have used for several years the portable magneto which I devised for the purpose of inspection testing. The shaft of the driving pulley is at right angles to the armature, and this allows it to be placed in a small flat rubber case which contains two flexible steel reels, each thirty feet in length, which serve as conductors between the circuit and the earth.

The value of this method of inspection which I have described,

is shown by the results following its adoption. In the autumn of 1881 and winter of 1882, twenty-three fires were caused by sixty-one electric lighting plants in mills insured by the Factory Mutual Insurance Companies in the eastern portion of the United States. The apparatus was inspected and the alterations necessary for safety specified and carried into effect, and there has not been a single fire from electric lighting apparatus on this property since that time, although the number of mills using electric lights has increased to nearly two hundred, and the average size of the plants been greatly enlarged. From being a legitimate cause of apprehension on the part of the underwriters, the hazard of electric lighting, in this field at least, has subsided into a matter of routine inspection.

There is a prospect of new matter at issue, which will tend to reverse the present conditions relative to safety in connection with the distribution of electric lighting. There is a widespread feeling of opposition to aerial electric wires, and several city governments, with the intrepidity of practical politicians, have passed ordinances decreeing that the wires must be buried.

In the present state of the art of supplying arc lights from central stations to scattered clients, the execution of such measures, if rashly entered upon, would be simply prohibitory, depriving the public of the enjoyment and protection derived from thoroughly lighted streets, and limiting its use to those who have boiler, engine, and complete electric lighting plant on their premises.

It is well known that the use of all underground electrical conductors is attended with special difficulties. On this occasion, it is necessary to confine the consideration of underground wires to conductors of electric lighting currents, as being the only phase of the question german to the subject.

Mr. Edison, with his inventive skill, supplemented by the immense financial resources of his company, has designed and laid a system of underground conductors for incandescent lighting from central stations, distributing lights over a small area in the denser portions of cities containing his stations. It serves its purpose, which is to conduct electricity at a tension of one-

thirtieth of that used on some arc lighting circuits. An insulation of sufficient resistance to be adequate for incandescent circuits would not be suited for arc-lighting conductors. Mr. Edison invented that system of underground conductors for the specific purpose of adapting it to his system of electric lighting; and relatively simpler as such a matter may be than the invention of a feasible method of burying arc-lighting wires under the present limitations of consumption, it may be noted that no other incandescent electric lighting interest has made any installation of any method of underground conductors. Portions of his central station circuits are above ground, as is the whole of his "village system" of lighting, and his "municipal system" is not only above ground, but uses electricity at an electro-motive force of 1,000 volts.

The distinctions between the conditions involved in the general problem of underground wires and those of an incandescent system feeding a limited territory have been stated, in order that this specific case may not be cited as a reason why all electric wires could be treated in a similar manner.

Like all parts of an electric light system, the conductors, whether aerial or subterranean, must be insulated from connection with the earth. For underground wires, this substance must possess a wide range of physical properties, in addition to high electrical resistance; it must be uninjured by extremes of moisture or dryness, or variations of natural temperature; it must not be acted upon by sewage or coal gas; not rendered defective by strains due to settling of buildings or the impact of traffic; furthermore, it must be cheap.

In all other forms of electric apparatus, a fault or leakage is merely an interference to the operation of the system; but in electric lighting a fault includes all this, and in addition the liability of as much injury to person or property as may be possible by the amount of energy diverted from the circuit.

The "clothes-line" system of overhead wires adds no beauty to the landscape, but that is no valid reason for its abolition, except to those adherents of Ruskin who may endorse his fierce diatribe against the railway system as destroying the beauties of natural scenery.

The few instances where wires over buildings interfered with ladders of the fire department might have been avoided by the further elevation of the wires, or by their crossing the streets at nearly right angles. In the natural course of improvement, the lines in cities are being changed from their scattered courses and systematised upon permanent fixtures high enough to carry the wires a reasonable distance above all roofs. Aerial wires certainly furnish the most ready means for Electric Companies to reach their customers, who are frequently distributed very unevenly over a city, and, like all other seekers after trade, may at times conflict with other interests.

The network of wires over cities serves as the most efficient protection against lightning, these conductors by their great number scattering the force of thunderbolts and conducting them to earth ; on this account thunderstorms are much more destructive in the country than in cities.

As for personal danger, a lineman is in infinitely greater danger from gravity than from electricity.

I repeat that most of the fires from arc-lighting systems have resulted in the diversion of the current by two contacts, one of them being a "ground" which had existed for an unknown time, and the second being an accidental "ground," generally of increasing resistance until it converted the electricity into heat whose temperature was high enough to ignite combustible material. When a "ground" exists anywhere on a circuit, this ground is trying to form a second circuit at the weakest point in the insulation anywhere on the whole circuit, irrespective of position. The one connection to earth may exist near the dynamo, and the other in some building at the extreme portion of the circuit, or it may be only a few inches away.

When the conductors are secured to elevated supports, they can readily be kept free from all such earth connections, and a casual inspection shows the place liable to defects, and the necessary changes can be made. With an underground system, this danger exists everywhere along the line, and is difficult of location and remedy, while the natural deterioration of material renders the hazard an increasing one.

Many underground arc-lighting circuits have received faithful trials without obtaining satisfactory results which would warrant their adoption by any form of American practice.

In this connection, I wish to cite several instances where such trials have been made. A large contract for lighting a park was offered to an Electric Lighting Company, upon the condition that the wires be placed underground. An Electric Light Company in Boston made preliminary experiments by laying 1,200 feet of one of their circuits, underground. The conductors consisted of No. 4 copper wire covered with rubber insulating composition one-eighth of an inch thick, and further protected by two thicknesses of cotton braid. The two wires of the loop were laid in grooves a foot apart in a plank laid three feet below the pavement, and covered by another plank. The resistance of the insulation of this circuit exceeded 90,000,000 ohms when first laid, but it diminished until the repairs made necessary by the frequent escapes became so burdensome that this underground line was abandoned, and a different line laid in a wooden conduit, with cleats arranged so that the wires could not approach nearer than a foot to each other. This second line consisted of the same size wire covered by a rubber insulating compound, and inclosed in a lead tube ; and this wire, like the former one, proved a failure in the course of a few months.

The faults were caused by a disintegration of the insulation, entirely different from anything similar resulting from the use of the same kind of insulation above ground.

At these places the wire would become vaporised and attenuate, similar to a pair of arc-light carbons, the connecting filament becoming smaller until an open circuit was established.

In Philadelphia, the escapes from an underground system of electric arc-light wires on Chestnut Street are believed to have been the cause of several severe explosions of illuminating gas leaking through the ground. On Delaware Avenue, in the same city, an underground circuit with different insulation received a careful trial, until the escapes through defective insulation, in spite of numerous repairs, diverted so much of the electricity from the circuit that the lights could not be maintained, and aerial

wires were substituted. The temperature of these escapes was so great that the sand was partially fused in places, and if the lights had been inside of buildings there would have been a liability of such points of excessive heat occurring in the presence of combustible material, with destructive consequences.

The result of a few weeks' experience with a short underground circuit is no measure of its capacity to fulfil the requirements necessary for central station arc-lighting, as it requires time to develop the faults in such conductors.

Aside from the question of overwhelming cost, there is no opportunity in cities to lay down subways without such serious interference with gas, water, and steam pipes, and sewers, that it would make their construction unfeasible. An underground circuit must be either a buried conductor or wires run through a conduit of small dimensions.

The insulation of buried conductors, from those of Prof. Morse in 1843 to the present day, has not been sufficiently permanent to reach satisfactory results, although such cables have given excellent results on submarine work, where they are free from many of the severe conditions imposed on them by underground service in cities.

It is clearly essential that the insulation upon wires in conduits must be supplemented by the material of the conduit also serving as an insulator.

In the oft-quoted subways of Paris, the wires are not in contact with the walls, but are attached to insulators fastened to beams placed tranversely across the subway, or against the walls, and are therefore suspended lines, surrounded by an insulation of air.

The use of underground systems would add to the obstructions of opened streets, increasing the measure of annoyance and danger arising from excavations in the highway, a difficulty which will increase in time, whether lines were successful or not, for if successful the increased patronage would require additional wires; and, if unsuccessful, the constant repairs and alterations, in the hope of obtaining satisfactory methods, would require certainly more occupation and interference with the highway.

Admitting each statement alleged against overhead wires, there would still remain the fact that the experiment of underground wires involves dangers and difficulties that should not be rashly entered upon, lest, like the discontented frogs in the fable, King Stork takes the throne of King Log.

In conclusion, it may be said—

1. That the present application of electricity forms a relatively safe method of lighting.
2. Underground wires conducting lighting currents contain elements of serious danger in proportion to their defects of insulation.
3. The compulsory burial of all electric wires would be oppressive to the electric interests.

Our methods of life are so closely interwoven with the uses of electricity that we are dependent upon its applications, especially to transmission of speech, telegraphy, and illumination, and any interference with the legitimate exercise of those interests will not be measured by the impaired value of plant, or load of excessive expenditures, but will be a detriment to each member of the community now benefited by its use.

REGULATIONS OF THE BOSTON FIRE UNDERWRITERS' UNION FOR THE USE OF ELECTRIC LIGHTING APPARATUS.

WIRES.

Conducting wires over buildings must be seven feet above roofs, and also high enough to avoid ladders of the Fire Department.

Whenever the electric light wires are in proximity to other wires, dead guard wires must be placed so as to prevent any possibility of contact, in case of accident to the wires or their supports. Conducting wires must be secured to insulating fastenings, and covered with an insulation which is waterproof on the outside, and not easily worn by abrasion. Whenever wires pass through walls, roofs, floors, or partitions or there is liability to abrasion, or exposure to rats and mice, the insulation must be protected with lead, rubber, stoneware, or some other

satisfactory material. Wires entering buildings must be wrapped so that water cannot enter through the tubes.

For inside use, loops of wire must be avoided, and the insulating fastenings arranged to keep the wires free from contact with the building.

Joints in wires to be securely made and wrapped; soldered joints are desirable, but not essential. Wires conducting electricity for arc lights must not approach each other nearer than one foot; and for incandescent lamps, the main wires must not be less than two and a half inches apart.

Care must be taken that the wires are not placed above each other in such a manner that water could make a cross connection.

A cut-out which can be operated by the firemen or police must be placed in the circuit in a well-protected and accessible place.

LAMPS.

For arc lamps, the frames and other exposed parts of the lamps must be insulated from the circuit. Each lamp must be provided with a separate hand switch; and also with an automatic switch which will close the circuit and put the lamp out, whenever the carbons do not approach each other, or the resistance of the lamp becomes excessive from any cause. The lamps must be provided with some arrangement or device to prevent the lower carbons from falling out, in case the clamp should not hold them securely.

For inside use, the light must be surrounded by a globe which must rest in a tight stand, so that no particles of melted copper or heated carbon can escape; and when near combustible material, this globe must be protected by a wire netting. Broken or cracked globes must be replaced immediately. Unless a very high globe is used, which closes in as far as possible at the top, it must be covered by some protector reaching to a safe distance above the light.

For incandescent lamps, the conducting wires leading to each building and to each important branch circuit must be provided with an automatic switch or cut-out, or its equivalent, capable of

protecting the system from any injury due to an excessive current of electricity.

The small wires leading to each lamp from the main wires must be very thoroughly insulated, and, if separated or broken, no attempt made to join them while the current is in the main wires.

DYNAMO MACHINES.

Dynamo machines must be located in dry places, not exposed to flyings or easily combustible material, and insulated upon wood foundations. They must be provided with devices capable of controlling any changes in the quantity of the current; and, if these governors are not automatic, a competent person must be in attendance near the machine whenever it is in operation.

Each machine must be used with complete wire circuit; and connections of wires with pipes, or the use of ground circuits in any other method, is absolutely prohibited.

The whole system must be kept insulated, and tested every day for ground connections at ample time before lighting to remedy faults of insulation, if they are discovered.

Preference is given for switches constructed with a lapping connection, so that no electric arc can be formed at the switch when it is changed; otherwise the stands of switches, where powerful currents are used, must be made of stoneware, glass, slate, or some incombustible substance which will withstand the heat of the arc when the switch is changed.

ABSTRACTS.

LORD RAYLEIGH—ON PROFESSOR HIMSTEDT'S DETERMINATION OF THE OHM.

(*Phil. Mag.*, *Vol.* 21, *No.* 128, *Jan.*, 1886, *pp.* 10–13.)

The leading feature in the method of Professor Himstedt is the use of a commutator or separator, by which the make-and break—induced currents are dissociated, one or the other passing in a stream at equal small intervals of time through a galvanometer. The commutator makes contact by means of mercury cups, and Lord Rayleigh points out how very capricious and uncertain such contacts are in their action. A second point raised relates to the measurement by the galvanometer of a series of induced currents, each of short duration. In Himstedt's method the needle of the galvanometer stands in an oblique position, and we have to consider whether the axial magnetisation does not alter under the action of a force having a sensible axial component. There is yet a third point which may be open to objection, viz., the determination of K, the constant expressing the number of turns of the primary of the induction coil per unit of length. Apparently the value of K is arrived at by dividing the whole number of turns, 2,864, by the total measured length, 135·125 cm.; but in so doing it is assumed tacitly that the turns are all perfectly uniform, or that only the mean value is required, both of which assumptions may be questioned.

Professor E. J. HOUSTON—PHOTOGRAPHY BY A LIGHTNING FLASH.

(*Journal Franklin Institute*, *Vol.* 91, *No.* 3, *March*, 1886, *pp.* 221–22.)

The view taken was that of the surrounding country near Philadelphia at 7 p.m. on the 29th Oct., 1885. The night was excessively dark, with much wind and rain. The camera was placed at an open window, with the slide drawn, and immediately after the flash the slide was returned. The plate—a highly sensitive gelatine film—was reversed, and exposed a second time.

From the behaviour of the plates on development, it was estimated that the actinic effect of the light was equivalent to that obtained by an exposure of $\frac{1}{100}$th of a second in bright sunlight. It is possible, therefore, that the average severe flash lasts a longer time than is generally supposed. The author has himself observed motion of foliage under illumination from a flash of lightning; and this observation is confirmed by the photographs above mentioned, in which it is unmistakably evident that the foliage has moved during the time of exposure. It would appear, therefore, that photography may be used advantageously to determine the duration of a flash of lightning.

EDISON'S SYSTEM OF TELEGRAPHING WITH TRAINS IN MOTION

(*Scientific American, Vol.* 54, *No.* 8, *Feb.* 20, 1886.)

The receiving apparatus at both the car end and the fixed end of the line is a telephone. The sending apparatus is also similar at both ends, and consists of an interruptor or vibrating tongue driven by an independent battery, and making 500 vibrations per minute; this vibrator is in circuit with the line battery, an ordinary Morse key, and the primary of an induction coil. The secondary of the induction coil on the car is in connection with the tin covering the entire roof of one or more cars; the secondary coil at the fixed station is in connection either with condensers or with other induction coils, which in turn are in connection with the ordinary line wires by the side of the track. Suppose a message to be sent from the fixed station to the car. The vibrator is always working, but till the Morse key is put down no current passes. The message is sent by the ordinary Morse signal, only instead of a continuous current being sent to line each time, it is an alternating one; this induces a current in the secondary coil, and through it the condensers, for example, are charged alternately. The charge of the condensers is propagated through the line wires with which they are in connection, and influences the tin roof of the car, and ultimately the telephone by which the signals are read.

CORNU and POTIER—EXPERIMENTAL VERIFICATION OF VERDET'S LAW IN DIRECTIONS NEAR THE PERPENDICULARS TO THE MAGNETIC LINES OF FORCE.

(*Comptes Rendus, Vol.* 102, *No.* 8, *pp.* 385–91.)

Former verifications have only been carried out for the directions where the magnetic rotary power is considerable, and the authors thought it desirable to go further—to the directions where the rotation becomes nil.

Faraday having discovered that the magnetic rotation ω becomes nil in the direction perpendicular to the lines of force, and changes sign when the pencil of light passes from one side to the other of this direction, it follows that the angle ω is an uneven function of the angle β which the pencil makes with the direction at right angles to the lines of force.

$$\omega = b\,\beta + c\,\beta^3 + \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

The question is if the term β really exists. From the existence of this term follows the consequence that the two surfaces cut each other at a finite angle proportional to b.

If Verdet's law is exact, this term does exist, for the law may be written in the form

$$\omega = a \cdot \cos.\left(\frac{\pi}{2} - \beta\right) = a \cdot \sin.\,\beta = a\left(\beta - \frac{\beta^3}{6} + \ldots\right) \ldots \qquad (2)$$

The chief experimental difficulties were to obtain a very intense field, which should also be uniform. The former was overcome by the use of peculiarly-shaped electro-magnets, powerfully excited, between which was sus-

pended a tube containing a saturated solution of iodide of mercury and iodide of potassium, which possesses three times the rotary power of bisulphide of carbon. The second condition was much more difficult to fulfil, but it was at the same time not so essential for the verification. It was, in fact, sufficient to prove the equality of the rotations produced by two columns of unequal length, but the extremities of which were respectively situated on the same two equipotential surfaces. The experiment was carried out by placing in the horizontal symmetrical plane of the electro-magnets a tube, having at its centre a cross branch one-tenth as long, filled with the solution above mentioned. The results obtained verified Verdet's law so far as the apparatus was capable of doing so, and any small differences may be attributed to non-uniformity of the magnetic field.

A. LEDUC—DEVIATION OF THE EQUIPOTENTIAL LINES AND VARIATION OF THE RESISTANCE OF BISMUTH IN A MAGNETIC FIELD.

(*Journal de Physique, Vol.* 5, *Mar.*, 1886, *pp.* 116–23.)

A strip of bismuth, 54 mm. long, 32 mm. wide, and 0·0233 mm. thick, is immersed in a vessel of distilled water, which is placed between the poles of a powerful electro-magnet, excited by a current of 38 ampères. The current passes through the strip of bismuth in the direction of its length, while two points in the other two sides of the strip are brought to the same potential. As the resistance varies not only with the strength of the field, but also with the temperature, it was necessary to make two series of observations. The effect of the magnetic field is shown by the following figures:—Magnetic field equal 0, R = 0·0333; magnetic field equal 5,000 units, R = 0·0354; magnetic field equal 10,000 units, R = 0·0387—an increase of 16 per cent. The experiments showed that the deviation of the equipotential lines is independent of the current passing, but that it depends on the strength of the field and on the temperature, and that it does not exceed 5°. The deviation may be expressed by the following formula, where M is the strength of the magnetic field and t the temperature:—

$$D = KM(1 - AM + BM^2 + CM^3)(1 + Pt - Qt^2).$$

The values determined for the several constants are—

$K = 158 \times 10^{-7}$	$C = 303 \times 10^{-15}$
$A = 882 \times 10^{-7}$	$P = 844 \times 10^{-5}$
$B = 112 \times 10^{-11}$	$Q = 862 \times 10^{-7}$

E. HOSPITALIER—INSTALLATION OF ELECTRIC LIGHT AT TOURS.

(*L'Electricien, Vol.* 10, *Nos.* 148 *and* 149, *pp.* 97–100 *and* 113–15.)

This installation is made on the Gaulard and Gibbs system of secondary generators or transformers. At the central station are two compound steam

engines, driving two Siemens alternate-current machines with their two exciters; the 30 bobbins of the alternate-current machines are coupled up so as to give a current of 32 ampères, with an E.M.F. of 2,500 volts, the number of alternations being 16,500 per minute. From these machines the current goes out into the main conductors through the town. The secondary generators, which are a special form of induction coil, are arranged in parallel circuit on these main conductors. There are four groups of these secondary generators, all similar. Each group consists of two generators of two columns, with a closed magnetic circuit for each two columns. Each column has a separate primary and secondary circuit, built up of discs of copper, the centre of the discs being cut out to allow of the passage of an iron core. From the secondary generators the service lines go to each subscriber's house or shop. As all the transformers are arranged in parallel, it is necessary to maintain a constant difference of potential at the terminals of the machines; this is done by altering their exciting current. By means of a special apparatus the regulation may be made automatic, the apparatus putting in or taking out resistance as necessary.

E. GERARD—LOCALISATION OF FAULTS BY MEANS OF A TELEPHONE.

(*La Lumière Electrique, Vol.* 19, *No.* 9, *pp.* 408–10.)

One end of the line is insulated; the other end is put in connection with a vibrator, by means of which alternating currents can be sent into the line from a battery, the other pole of which is to earth. If now a person walks along the line carrying in one hand a coil with an iron core, and in the other a telephone in connection with the coil, the inductive action of the current in the line will cause the telephone to sound; but the sound will stop as soon as the fault is reached. The experiment has been practically made by the author, and the fault located exactly. The method is especially useful in the case of underground electric light cables, where, owing to their very low resistance, the ordinary methods of testing would fail to localise the fault exactly, and it would become necessary to open a considerable length of ground. The coil used should have as many turns as possible, and its resistance should approximate to that of the telephone used; the core should consist, preferably, of a bundle of iron wires. One of the chief advantages claimed by the author is that the method can be carried out successfully by an unskilled person, and he believes it to be capable of considerable development.

F. and W. KOHLRAUSCH—THE ELECTRO-CHEMICAL EQUIVALENT OF SILVER; AND AN EXPERIMENTAL PROOF OF THE EARTH'S MAGNETIC INTENSITY.

(*Annalen der Physik und Chemie, B.* 27, *Pt.* 1, *No.* 1, 1886, *pp.* 1–59.)

This is a detailed account of two very elaborate series of experiments carried out in the years 1881 and 1883, with the view of determining very exactly the

electro-chemical equivalent of silver, from which the equivalents of all other bodies can then be derived.

The method consisted in measuring simultaneously the quantity of silver deposited in a voltameter, and the strength of the current used for the electrolysis. This latter was measured by a tangent galvanometer, and it became, therefore, necessary to determine very exactly the value of H, not only for the place—the Physical Laboratory at Wurzburg—where the experiments were made, but even for the very pillar on which the galvanometer stood. Very accurate determinations of the minutest variations in the value of H had also to be made during the whole time of the experiments, so that the proper corrections could be made.

In 1881 the absolute measurement of H was made in the first instance by the Gaussian method, in which, firstly, from the moment of inertia of a magnet and its time of oscillation under the influence of the earth alone, the product of its magnetic moment into the horizontal intensity is determined, and, secondly, the quotient of the former by the latter, by observations of the deflections of the same magnet under the influence of fixed magnets in its neighbourhood. Besides this method, the bifilar galvanometer was also used in 1881 to measure H; in 1883 this latter method only was employed.

The local and diurnal variations of H were kept constantly under observation by means of an instrument to which the authors have given the name of "local variometer with four deflecting magnets," by means of which values correct within one ten-thousandth could be obtained.

The tangent galvanometer used in 1881 was constructed of a single ring of copper strip, at the centre of which was suspended a magnetised steel mirror by means of a fibre. The value of the current can then be obtained from the deflection of the needle, when the following constants of the galvanometer have been once determined, viz.: the mean radius of the copper ring, its thickness, its breadth (since it was of square section), the length of the connection pieces where the ring was divided, their distance apart, and the diameter of the steel mirror. All corrections made, the following formula gave the current (i) at 13° C.:—

$$i = 3{\cdot}20724 \text{ H tan. } \theta \ (1 + 0{\cdot}0048 \text{ sin.}^2 \theta),$$

in which the second term in the bracket is a correction for the removal of the needle from the mean plane of the current circulating in the ring.

In 1883 a different galvanometer was used. It consisted of a circular disc of glass, such as is used in frictional machines, in the edge of which was a shallow groove, in which was a copper wire. In the centre of the glass was cut a circular opening, in which was suspended the magnetised mirror. The opening was only slightly larger than the mirror, and was covered at back and front by small glass plates fixed in ivory rings, so as to form a box in which the mirror formed its own air-damper. In the construction of this instrument, all metal was rigorously excluded except for the single turn of wire and the needle, the materials used being chiefly glass and ivory. The actual measurement of the current was made by means of a reduction factor as described above, with the necessary changes for changes in the form of the instrument.

Two forms of voltameter were used, the one a platinum capsule as kathode, the anode consisting of a silver rod suspended vertically above it; while in the other case separate vessels, connected by a syphon, were used for the kathode and anode.

Every possible refinement was used in making the actual measurements, and the following are the final results:—

1881:	H by Gaussian method ...	0·19396
„	H by bifilar method ...	0·19399
„	Electro-chemical equivalent	1·11833 $\frac{\text{mg.}}{\text{sec. amp.}}$
1883:	H by bifilar method ...	0·19410
„	Electro-chemical equivalent	1·11822 $\frac{\text{mg.}}{\text{sec. amp.}}$

Hence a current of 1 ampère deposits in 1 second 1·1183 milligrams of silver, or 0·328 milligrams of copper, or 0·010386 milligrams of hydrogen; or it decomposes 0·09327 milligrams of water, producing 0·174 cubic centimètres of mixed gases measured at 0° C. and 760 mm. pressure—these values being all correct within one-thousandth.

A. KUNDT—DOUBLE REFRACTION OF METALLIC FILMS.

(*Annalen der Physik und Chemie*, B. 27, *Pt.* 1, *No.* 1, 1886, *pp.* 59–72.)

A vertical glass cylinder, about 10 cm. wide, can be closed at top and bottom by glass plates into which vertical glass tubes are fused. Into the lower one is fused an electrode of aluminium; in the upper one the electrode of the metal to be experimented upon is introduced through an india-rubber cork. The glass plate on which the deposit is to be formed is placed on a glass three-legged stool immediately below the kathode. The whole apparatus can be exhausted of air by means of a mercury pump. On passing a discharge from an induction coil, worked by 3 to 6 Bunsen cells, through the apparatus, which is only a special form of Geissler's tube, the kathode becomes disintegrated and a deposit of metal in the form of a film appears on the glass plate. In the case of readily oxidisable metals, the experiments were carried out in an atmosphere of hydrogen.

When the metallic mirrors thus formed are looked at under the microscope they appear coherent and homogeneous, and generally show Newton's rings; but on looking at them with two crossed Nicol's prisms, it was found that they were doubly refractive. The axes of the double refraction—*i.e.*, the undulatory planes along which the plane polarised light was decomposed—were in different directions in different positions of the mirror. The electrode was generally in the form of a straight wire about 2 cm. long and 0·2 to 0·5 mm. thick, and the deposited metal arranged itself in form of a conical film, the apex being immediately under the electrode. The thickness of these films was less than 0·00001 mm. at the thickest point. Most of the experiments were made with platinum, which lent itself most readily to the process; but palladium, gold, silver, iron, and copper were also experimented upon.

On examining one of these metallic films between crossed Nicols, either with the naked eye, or, better, with a telescope, by means of parallel sunlight, a bright field is seen with a black cross upon it. The point of intersection of the arms of the cross lies at the apex of the conical film, *i.e.*, immediately under the kathode; the arms of the cross coincide with the undulatory planes of the light in the polarising and analysing Nicol. Just the same phenomenon was observed when the light was reflected from the film, instead of being transmitted by it; and it was immaterial whether the light was reflected directly from the front of the metallic film, or from the back through the glass plate.

The author puts forward four possible hypotheses in explanation of the phenomenon:—(1.) It is due, not to the metallic film, but to the glass plate. (2.) It is due to the conical form which is assumed by the film. (3.) It is due to the film being in a condition of strain. (4.) It is due to a crystalline arrangement of the atoms of the metallic film.

The first is shown at once to be untenable, since the phenomenon was not observed when the glass plate was examined before the metal film was deposited upon it, nor after the film had been washed off with acids. The second hypothesis is upset by the experiment already described, viz., that the double refraction was equally active whether the light was reflected from the front *conical* surface of the metal, or from the back *plane* surface in contact with the glass plate. The third hypothesis was very carefully investigated experimentally by producing strains either by unequal heating of the film or by pressure, but no double refraction could be recognised on analysing the reflected light.

In the author's opinion, therefore, the fourth hypothesis of the crystalline form of the metal must be taken as the cause of the double refraction. This crystalline form of the metal is itself due to the action of the kathode on the disintegrated particles which leave it. Since the discharges are interrupted, each molecule separated from the electrode is charged with electricity; and if the distribution of the electrical charge is not a regular one, each molecule will be influenced in its motion by the electrode, and will be constrained to follow a particular path.

In the case of oxidisable metals the films, which are no longer metallic, but oxide films, show beautiful interference bands, but no trace of double refraction. If a film of copper which has been deposited in an atmosphere of hydrogen is examined, it will show the black cross on a bright ground; but this at once disappears if the film is heated, whereby it is converted into oxide of copper. This destruction of the doubly refractive power cannot be accomplished in the case of platinum, which metal does not readily oxidise.

If similar conical films are obtained by electrolysis, instead of by discharges in vacuo, no trace of double refraction can be discovered.

H. AULINGER — ON THE RELATION OF WEBER'S ELECTRO-DYNAMICAL THEORY TO HERTZ'S PRINCIPLE OF THE UNITY OF ELECTRIC FORCES.

(*Annalen der Physik und Chemie*, *B.* 27, *Pt.* 1, *No.* 1, 1886, *pp.* 119-132.)

The principle of Hertz referred to may be expressed thus:—If at every point in a finite or infinite space (electro-magnetic field) the quantity and the direction of the electrostatic force (*i.e.*, the force which acts on a unit quantity of electricity motionless at that point) and the quantity and direction of the magnetic force (*i.e.*, the force which acts on a unit north pole at that point, also motionless and unchangeable) are given, then the whole of the electric and magnetic forces which in the whole field act on movable and changeable electricities and magnetisms are entirely and certainly determined, no matter what the origin of the electric and magnetic forces may be.

The author investigates mathematically what is the relation of the above principle to Weber's theory, and what follows from it with respect to the mutual action of two infinitesimal ring magnets.

O. TUMLIRZ—BEHAVIOUR OF QUARTZ IN THE MAGNETIC FIELD.

(*Annalen der Physik und Chemie*, *B.* 27, *Pt.* 1, *No.* 1, 1886, *pp.* 133-142.)

The experiments were made with two plates of quartz cut at right angles to the optic axis, the one being dextro-rotary, the other lævo-rotary. Both plates were very carefully cleaned and suspended in silk fibre loops. The dextro-rotary plate was then hung in the position shown in Fig. 1., where *a* is the point of intersection of the suspending fibre with the plane of the drawing.

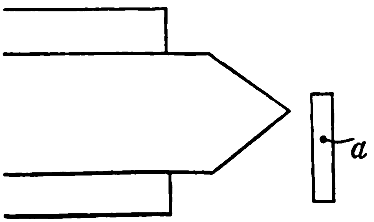


FIG. 1.

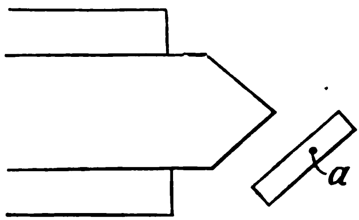


FIG. 2.

The direction of the cocoon fibre coincided with one minor axis, so that the principal axis and one minor axis lay in a horizontal plane. The distance from the pole-piece was 1 to 2 mm.

In the first experiment one pole-piece only was used, and on closing the circuit the quartz plate took up the position shown in Fig. 2. On interrupting the circuit, the plate began to oscillate about its former position, and touched the pole-piece. On its approaching again, the current was closed suddenly, when not only was the motion of the quartz arrested, but it was repelled. No difference occurred if the lævo-rotary quartz was used in place of the

dextro-rotary, nor if the polarity of the electro-magnet was reversed. Quartz is therefore diamagnetic.

Both pole-pieces of the magnet were then used, and they were brought so close together that the quartz had just room to oscillate. On completing the circuit, the principal axis placed itself neither axially nor equatorially, but at an angle of about 20° with the line joining the two poles; on reversing the current, the quartz took up a new position symmetrical with respect to the former one. These experiments were then repeated in a homogeneous magnetic field, the quartz being hung in a bifilar suspension of small torsional moment, and with its principal axis in the equatorial position. On closing the circuit, the quartz took up a new position of equilibrium, in which the principal axis made an angle of about 60° with its former position. The cause can only be due to a permanent polarity which does not exist naturally in the quartz, but it induced by the magnetic forces acting on it. It should therefore be possible to determine the kind of magnetism. If we call A that side of the quartz which was opposite the north pole when it was magnetised, and B the other side, then, since quartz is diamagnetic, the side A should be repelled from the north pole and attracted by the south pole, while the reverse holds good for B. Experiment, however, showed exactly the contrary, for the quartz behaved as though it were magnetic. This took place also when one of the minor axes was in the equatorial position. Quartz, therefore, is the first diamagnetic body which shows a permanent polarity, not only in the direction of the principal axis, but in all directions at right angles to it.

C. L. WEBER—CONDUCTIVITY OF SOME EASILY FUSIBLE ALLOYS.

(Annalen der Physik und Chemie, B. 27, Pt. 2, No. 2, 1886, pp. 145–150.)

The following table shows the alloys experimented upon :—

Alloy.	Composition.			
	Bismuth.	Tin.	Lead.	Cadmium.
Rose's	48·90	23·55	27·54	—
Wood's	55·74	13·73	13·73	16·80
Lipowitz's	49·98	12·76	26·88	10·38

The several constituents were in each case melted together in an atmosphere of hydrogen, so as to prevent any formation of oxide. The resistance of each was then determined at very various temperatures. For this purpose the alloys were introduced into U-shaped capillary tubes, which were heated in a glycerine bath, the measurements being made by means of Thomson's modification of the Wheatstone bridge.

An inspection of the curves plotted from the values obtained shows at once how little the resistance decreases with change of temperature so long as the

alloys are in the fluid state. The temperature coefficient for Rose's metal, when fluid, is 0·0007; for Lipowitz's, 0·0005. On solidification there occurs a sudden and considerable fall in the resistance, as is the case also with pure metals in a still greater degree. This decrease is, for Rose's metal, 20 per cent., and for Lipowitz's, 54 per cent. of the resistance shown by the solid alloys at the melting point; for pure tin the decrease is 100 per cent., and for mercury 400 per cent. On further cooling the alloys which have now solidified the decrease is again regular and small, until at about 20°–30° there is a second sudden fall, equally well marked as the first, but very much less in degree.

On comparison of the curves above mentioned with those showing the change of volume of the alloys during change of temperature, it is apparent that they do not follow parallel paths; whilst in the case of the volume, especially in Rose's metal, the curve shows several maxima and minima, in the case of the resistance the tendency is always towards a single minimum with decrease of temperature. The change of resistance is not due to a change of volume, but both are probably due to a third cause, viz., a rearrangement of molecules.

If the alloys are gradually heated instead of being cooled, the results are somewhat different. Thus, in the first place, there is a continuous steady increase from 0° to the melting point, the steep point of the curve between 20°–30° being no longer apparent; and, secondly, the principal sudden rise occurs at a higher temperature than was the case on cooling. There is also a peculiarity in the behaviour of Rose's metal in the neighbourhood of its melting point, when it is cooled down: the curve of resistance, after falling very gradually, becomes at once steeper, and continues as a straight line until about 70°, when the sudden fall occurs. It would appear as though there were an intermediate stable state of the alloy between a fluid and a solid. This may be explained on Wiedeman's hypothesis that at the temperature of 69°, which is generally looked upon as the melting point of Wood's metal, only a portion of the alloy fuses, in which the remainder is gradually melted as the temperature rises; so that we cannot consider that we have to do with a homogeneous fluid until after we reach 90°.

E. KLEIN—CONDUCTIVITY OF DOUBLE SALTS.

(*Annalen der Physik und Chemie*, *B.* 27, *Pt.* 2, *No.* 2, 1886, *pp.* 151–178.)

From a consideration of the labours of other observers, it appears that in general, on solution of a double salt, dissociation always occurs, and that the only distinction which has to be made is between total and partial decomposition. A knowledge of the conductivity of double salts may be of service in making this distinction.

The measurement of the resistances was effected by the use of a Wheatstone bridge, worked with alternating current and telephone. The salts experimented upon were the following:—$Mg\,SO_4$, $(NH_4)_2\,SO_4$, $K_2\,SO_4$, $Fe\,SO_4$, $Mn\,SO_4$, $Ni\,SO_4$, $Na_2\,SO_4$, $K\,Cl$, $Na\,Cl$.

In the first set of experiments, solutions of simple salts only were investigated, and the exact results are tabulated for various degrees of strength of the solutions. One of the striking points is that the sulphates of iron, manganese, and nickel have nearly the same conductivities, which are relatively low ones. The alkaline salts, on the other hand, have relatively high conductivities.

Taking the three first-named sulphates, it has been possible, by the method of least squares, to obtain a formula for the conductivity in terms of the strength of the solution, viz.—

$$10^8 k = 339{\cdot}24\, m - 111\, m^2 + 15{\cdot}05\, m^3.$$

In this formula m is the so-called "molecular number," and is defined by the expression

$$m = \frac{p\, s}{A} \times 1{,}000$$

where p is the weight of the electrolyte in one part by weight of the solution, s is the specific gravity of the solution at 18° C., and A is the electrochemical molecular weight—that is, the chemical molecular weight divided by the valency. The calculated results agree extremely well with those derived from experiment.

The second series of experiments was on mixtures of the several salts, two together. Two kinds of mixtures have to be distinguished, the first of which may be represented by $A\,B + A\,B^1$ or $A\,B + A^1\,B$, where we have either one acid and two bases or one base and two acids; where probably no decomposition takes place. In the second, on the other hand, in which we have $A\,B + A^1\,B^1$, *i.e.*, two acids and two bases, double decomposition may take place. From the results of the experiments on mixtures it would appear that up to a moderate degree of concentration the conductivity of a mixture is equal to the arithmetical mean of the conductivities of its constituent salts. It seems, moreover, that two solutions, one of which contains $A\,B + A^1\,B^1$, and the other $A\,B^1 + A^1\,B$, are identical.

The third series dealt with the conductivities of double salts formed from the same list as given at the beginning; and the experiments showed that the conductivity of the double salt differs somewhat from the arithmetical mean of the conductivities of the two component salts. Experiments were also carried out on mixtures of double and simple salts, and on the effect of temperature, the results of which are all tabulated.

The conclusions to which the research leads are thus summed up by the author:—

1. If there are two salts in a solution, which can or cannot act on each other by double decomposition, the conductivity of the mixture (in dilute solutions) is nearly equal to the mean of the conductivities of those salts which most probably exist in the solution.
2. Conversely from the conductivities we may conclude which are the two salts most probably existing in the solution.
3. The conductivity of the double salts experimented on is, in dilute solutions, a trifle less than the mean, in concentrated solutions certainly less. The difference is about proportional to the "molecular number."

4. The double salts are entirely decomposed in dilute solutions, and more or less in concentrated ones. The amount of dissociation increases with the degree of dilution.
5. The application of heat assists the dissociation.

F. STREINTZ and E. AULINGER—POLARISATION OF LEAD.

(*Annalen der Physik und Chemie, B.* 27, *Pt.* 2, *No.* 2, 1886, *pp.* 178–86.)

A preliminary series of experiments was made by Fuchs's method to determine what share the hydrogen evolved at the negative electrode has in the value of the polarisation. The lead plates were in a vessel containing a 10 per cent. solution of sulphuric acid, and were charged from a battery of three Daniell cells; by means of a capillary syphon tube this vessel communicated with a second one in which was a zinc plate in concentrated solution of sulphate of zinc. The lead plate at which the hydrogen was evolved was in connection with one pair of quadrants of an Edelmann's electrometer, and with earth; the zinc plate being connected to the second pair of quadrants. The standard of comparison was a Latimer Clark cell giving 1·433 volt at 15·5° C. Half an hour after closing the circuit of the charging battery, the difference of potential Zn | Pb + H was – 0·26 volt, which rose to 0·29 volt in an hour, and became 0·45 volt on opening the circuit of the charging battery. This last value was maintained for some time, and it was only after several hours that it reached 0·75 volt, the difference previously found for Zn | Pb. This behaviour of the lead plate may be explained by the assumption that it is only so long as nascent hydrogen is evolved that it causes a polarisation, and when the evolution of gas ceases the polarisation ceases.

A different mode of operating was then adopted, by means of which the potential of either lead plate could be compared with that of a zinc plate in sulphate of zinc by means of an electrometer, at the same time that the discharge current was measured on a galvanometer. From the tables of results it is apparent that the E.M.F. almost immediately attains a value which approximates to that between metallically clean lead and zinc. The difference of potential between the zinc and the lead plate at which hydrogen is evolved increases slowly during the first three minutes that they are connected to the electrometer, and rapidly during the fourth minute, soon after which there is a sudden jump to a much higher value, which afterwards only increases very slowly. The value of the current meantime decreases proportionately to the increase of the E.M.F. The behaviour of the plate covered with peroxide is very different: at the very beginning its potential, compared with zinc, is very much higher than that of the other plate, and only diminishes by about $\frac{1}{10}$th volt in the first half minute, after which it remains practically unaltered.

From the experiments it may be concluded that just as the lead plate covered with peroxide is the carrier of the chief E.M.F., so the plate covered with hydrogen is the source of its falling off. The discharge of the couple is not due to the de-oxidation of the peroxide plate, but to the oxidation of the

metallic plate. Whilst, therefore, the hydrogen evolved on the depolarisation does not suffice to reduce the whole of the peroxide of the one plate, the oxygen evolved is sufficient to cover the metallic plate with a layer of oxide, or even of peroxide.

A. FÖPPL—METHOD FOR THE DETERMINATION OF THE MAXIMUM OF GALVANIC POLARISATION.

(*Annalen der Physik und Chemie, Vol.* 27, *Pt.* 2, *No.* 2, 1886, *pp.* 187-91.)

The new method proposed is similar to the compensation method. The principle underlying both is to form two different circuits, which have one part in common, and arrange the resistance of this part in such a way that no current passes in the one circuit. From the length of the wire necessary for this purpose in the one case, or from direct measurement of the difference of potential in the other, the value of the E.M.F. to be measured can be determined.

The arrangement adopted is the following:—A voltameter, with platinum plates in dilute sulphuric acid, is joined up permanently in simple circuit with a battery. On opposite sides of the battery are two points, A and B, in the circuit. At A is a mercury cup; at B is a permanent connection with one end of a resistance, the other end of which can make contact with the mercury cup at A, and thus serve as a shunt. From the pole of the voltameter nearest to A a wire leads to a galvanometer, the return wire from which comes also to the mercury cup A. When required, an electrometer can be connected to the points A and B.

To determine the polarisation produced in the voltameter by the current from the battery, both the free end of the lead to the galvanometer and the free end of the resistance are dipped simultaneously into the mercury cup A. If now the resistance is comparatively large, a part only of the current is shunted, and the remainder continues to pass through the voltameter; this remainder then divides itself between the original circuit and the galvanometer circuit. If the resistance is very small, not only will the whole of the current from the battery be shunted, but a polarisation current will start from the voltameter in the opposite direction to the original charging current. By adjustment of the resistance it is therefore possible so to arrange matters that no current flows in the voltameter portion of the circuit; and when this is the case the E.M.F. of the polarisation is equal to the difference of potential at the ends of the resistance A and B, which can then be measured on the electrometer. Two assumptions are made in this method, viz., that the E.M.F. of the charging battery remains constant, and that the resistance does not alter; it is hence necessary to make sure that the latter is not increased by its being heated by the passage of the current.

A. KUNDT—ELECTRO-MAGNETIC ROTATION OF THE PLANE OF POLARISATION IN IRON.

(*Annalen der Physik und Chemie, Vol. 27, Pt. 2, No. 2, 1886, pp.* 191–202.)

The magnetism induced in iron, cobalt, and nickel is not proportional to the magnetising force, but—at least in the case of iron—it at first increases more rapidly, then more slowly, and finally reaches a saturation point. It becomes, then, interesting to investigate if the rotation of the plane of polarisation in iron is in proportion to the magnetisation or to the magnetising force. The experiment soon showed that the rotation is not proportional to the magnetising force, but reaches a maximum value which is not increased by increasing the magnetising force.

The electro-magnet employed was a very large one of Ruhmkorff's construction, excited by a current from a Gramme dynamo. The small portion of the field of force between the pole-pieces could be considered as quite uniform. The iron films used were formed by electrolytic deposition on platinised glass (see Journal, vol. xiv., p. 68), which before the iron was deposited on it gave a rotation of 20′ to 30′. The strength of the magnetic field was measured by means of the rotation produced by a certain piece of glass. The constant of rotation of this piece of glass having been compared once for all with that of water or bisulphide of carbon, the strength of the field in each case could be calculated in absolute units by means of Verdet's constant. The source of light was the C line of the solar spectrum.

The course of the observations on one mirror will serve as an illustration of the relation of the rotation to the intensity of the field:—

Rotation in Glass.	Intensity of Field, $c^{-\frac{1}{2}} g^{\frac{1}{2}} s^{-1}$	Rotation in Iron.
0·72°	4,610	3·58°
1·47°	9,410	6·34°
2·18°	14,000	8·82°
2·85°	18,200	9·67°
4·56°	29,200	9·71°

By careful weighing of the small mirrors it was possible to arrive at an average value for their thickness, and so to determine what was the maximum rotation for unit of length through which the light passed. It was found that the simple rotation in one centimètre of iron, magnetised to saturation, would be roughly 200,000°, or the maximum rotation in angular measure for one-hundredth of a millimètre is rather more than π. This maximum value was obtained in a field of 20,000 units. Very similar results were obtained when the light was reflected from the film of iron instead of being transmitted through it, it being found here also that the rotation is not proportional to the magnetising force.

The author has also investigated the negative rotation produced by solutions of magnetic salts, and he suggests that all the chemically simple bodies hitherto investigated, whether they are strongly magnetic or dia-magnetic, show positive electro-magnetic rotation; negative rotation is produced only by chemically compound bodies.

L. SOHNCKE—ELECTRO-MAGNETIC ROTATION OF UNPOLARISED LIGHT.

(*Annalen der Physik und Chemie, Vol. 27, Pt. 2, No. 2, 1886, pp.* 203–19.)

Although the phenomenon of the rotation of the plane of polarisation by electro-magnetic forces has frequently been investigated since Faraday's discovery, their action on ordinary unpolarised light has not received any attention. Two plane polarised rays of light proceeding from the same source cause interference when they are polarised in parallel planes, but no interference is produced if they are polarised at right angles to each other. Ordinary light behaves as light polarised in parallel planes, and consequently it will lose its power of interference if by means of electro-magnetic forces the plane of undulation of one of two rays proceeding from the same source can be turned through 90°, thus furnishing us with a means of testing the question raised.

The experiment was carried out by causing the rays of unpolarised light, which would produce interference bands, to pass through a double quartz prism, whereby the interference was annulled. They then passed through two cylinders of Faraday's glass which were placed inside two solenoids, and if the current in these latter had any effect, the interference bands would again appear. The experiment was most successful, as always, on closing the circuit of a Schuckert dynamo giving a current of 20 amperès through the solenoids, the interference bands at once became apparent. It was found that not only was the plane of undulation of the light rotated by the electro-magnetic force, but that the rotation was in the same direction for ordinary light as for polarised light.

F. KOHLRAUSCH—A SIMPLE ABSOLUTE CURRENT MEASURER FOR WEAK ELECTRICAL CURRENTS.

(*Annalen der Physik und Chemie, Vol. 27, Pt. 3, No. 3, 1886, pp.* 403–409.)

The instrument was specially designed for the measurement of currents of from one to ten milliampères, and is intended chiefly for use in connection with medical electricity.

On a wooden base, provided with levelling screws, is fixed vertically a solenoid of about 10,000 turns of very fine copper wire, having a resistance of about 1,000 ohms. Inside the solenoid is hung by a spiral spring of German silver wire a magnetised steel needle 90 mm. long, which, when no current passes in the instrument, enters the solenoid for a distance of 20 mm. On passing a current, the needle is drawn further into the solenoid, and the consequent stretching of the spring serves as a measure of the current. At the top of the needle is fixed a horizontal horn disc, which serves as an index, and also as an air damper in the glass tube surrounding the spring and needle, on which tube is engraved the scale. The instrument is calibrated by comparison with a standard, and the needle is found to retain its magnetism fairly constant. Should any alteration of magnetic moment occur, however, it is not of any great consequence, as the first effect of the current circulating in

the solenoid is to remagnetise the needle to its initial force. Though principally used for the measurement of currents amounting only to a few milliampères, larger currents can be measured by a choice of a suitable spring and solenoid.

A. FÖPPL—THE ABSOLUTE VELOCITY OF THE ELECTRIC CURRENT.

(Annalen der Physik und Chemie, Vol. 27, Pt. 3, No. 3, 1886, pp. 410–14.)

The author's plan is to cause a circular current to revolve in a horizontal plane around its centre; then the absolute velocity of the electric particles are altered. The apparatus used consisted of a multiplying coil which held two similar copper wires wound on side by side. To the coil was fixed a small glass cylinder containing dilute sulphuric acid in which were immersed a small strip of zinc and a platinum wire. The connection to the coil was so made that the current in the two halves flowed in opposite directions. The whole was mounted on a whirling table which could make about 20 turns per second, and so give a circumferential velocity of 500 cm. per second to the coil. The action of the coil was observed by means of a Wiedemann's galvanometer. With the connections made as described, the galvanometer needle was not deflected when the coil was brought near to it, nor was there any deflection when the coil was revolved at the speed above mentioned. On altering the connection so that the current in both wires of the coil was in the same direction, a considerable deflection was noted. From calculation it would appear that the velocity of the electric current in the case under consideration must be put down as greater than three kilomètres per second; that is, on the assumption of the translatory movement of one fluid.

E. EDLUND—RESISTANCE OF THE ELECTRIC ARC.

(Zeitschrift für Elektrotechnik, Vol. 4, No. 2, Feb., 1886, pp. 63–65.)

If the apparent resistance of the arc is measured in the ordinary way, it can be expressed by an equation $R = a + b\,l$; where a and b are constants, and l is the length of the arc. This is true so long as the current is maintained constant, but if the current increases b is diminished, while a is apparently independent of the current and E.M.F. of the source of electricity; only when the E.M.F. is so much diminished that an arc is scarcely formed is a somewhat diminished. The question arises whether a is a resistance due to the passage of the electricity from the carbon to the air, or if it has its origin in an E.M.F.; and it has generally been considered that it is of the nature of a counter E.M.F.

From the author's experiments with 55–79 Bunsen cells it follows that a is independent of the current. The mean value found for a was 23·315, and taking the Bunsen cell at 1·8 volt we get the value 41·97 volts. The mean of this value, of Frölich's (39), and of Peukert's (35), is 38·66 volts. Victor v.

Lang has shown (Journal, vol. xiv., p. 571) that the arc contains a counter E.M.F. which is equal to 39 volts. As this is very nearly equal to the value found for the constant a, it follows that a so-called transmission resistance (from carbon to air) does not exist, and that consequently the entire decrease of the current strength which occurs on introducing an arc is caused by the resistance ($b\ l$) of the arc and by the counter E.M.F.

LIST OF UNABSTRACTED ARTICLES.

(Nature.)

January 7, 1886.—Standards of White Light.

January 21, 1886.—Report to Trinity House on Lighthouse Illuminants.

(Proceedings of the Royal Society.)

December 10, 1885.—**S. J. PERRY and BALFOUR STEWART**—Simultaneous Fluctuations of the Declination at Kew and Stonyhurst.

January 21, 1886.—**LORD RAYLEIGH**—Clark's Cell as Standard of E.M.F.

January 28, 1886.—**E. W. CREAK**—Local Magnetic Disturbances in Islands far distant from Continents.

December 10, 1885.—**J. W. GEMMELL**—Magnetisation of Steel, Cast Iron, and Soft Iron.

(Philosophical Magazine.)

January.—**S. P. THOMPSON**—Law of the Electro-Magnet and Law of the Dynamo. **E. F. HERROUN**—E.M.F. of some Tin Cells. **W. M. MORDEY**—The Dynamo as a Generator and as a Motor. **T. MATHER**—Calibration of Galvanometers by a Constant Current. **AYRTON and PERRY**—Seat of the E.M.F. in a Voltaic Cell.

February.—**AYRTON and PERRY**—Winding of Voltmeters. **GORE**—Evidence respecting the Reality of "Transfer Resistance" in Electrolytic Cells. **GORE**—Relations of Surface Resistance at Electrodes to various Electrical Phenomena.

March.—**GORE**—On "Resistance" at the Surfaces of Electrodes in Electrolytic Cells. **O. LODGE**—Seat of the E.M.F. in Voltaic and Thermo-electric Piles.

(Electrical Review of New York.)

January 2, 1886.—Production of Alizarin by Electricity. Electric Brake, Action of Electricity upon the Human Body.

January 9, 1886.—New Apparatus for the Estimation of Copper.

January 23, 1886.—New Chloride of Silver Battery. Strength of Telephonic Currents.

February 6, 1886.—Abstract of Report to Lighthouse Board, U.S.A., on Electric Illumination for Lighthouses. Use of the Ammeter in Electro-deposition.

February 13, 1886.—Dorsett's Conduit System for Underground Wires.

March 6, 1886.—Pratt's Telephone System.

March 13, 1886.—Brown's Automatic Converter.

(*Electrician and Electrical Engineer.*)

January.—**D. E. LAIN**—Subterranean Wires in England. **C. HERING**—Commercial Efficiency of Glow Lamps. **G. B. PRESCOTT**—Ayrton & Perry's Meters. **A. C. WHITE**—Changes in the Cold Resistance of Glow Lamps. **D. BROOKS**—Induction.

February.—**F. J. SPRAGUE**—Application of Electricity to Propulsion on Elevated Roads. **E. E. REIS**—Carrying Electric Conductors through Cities. **C. HERING**—Size of Electrical Conductors. **C. F. HEINRICHS**—Tests and Efficiencies of Dynamos. *Anon.*—Subterranean System of the Standard Underground Cable Co.

March.—**W. L. HOOPER**—Correction of an Error in Electro-Dynamics. **E. R. WEEKS**—Proper Construction and Maintenance of Arc Lighting Circuits. **R. W. POPE**—Underground Wires for Arc Lighting. **C. J. van DEPOELE**—Progress in Electric Railways.

(*Journal of the Franklin Institute.*)

January.—**A. E. DOLBEAR**—Telephone Systems. **B. A. FISKE, U.S.N.**—Electricity in Warfare.

February.—**B. A. FISKE, U.S.N.**—Electricity in Warfare. **E. H. COWLEY**—Production of Aluminium and its Alloys in the Electric Furnace.

March.—**W. D. MARKS**—Development of Dynamic Electricity. **L. H. SPELLIER**—Contact Maker for Electric Clocks.

(*Scientific American.*)

January 23, 1886.—Method of Indicating Fire-Damp in Coal Mines.

February 13, 1886.—Improvements in Electro-Magnets. Electrolytic Cartridge for Blasting.

(*Comptes Rendus, Vol.* 102.)

No. 1.—**T. MOREAUX**—Actual Value of the Magnetic Elements at the Observatory of the Park St. Maur.

No. 2.—**M. MASCART**—Magnetic Storm of 9th January, 1886. **FAYE**—Applications of Electrical Transmission of Power made by the Artillery.

No. 3.—**LECOQ DE BOISBAUDRAN**—Electric Spectrum Characteristic of the Terbium Group of Rare Metals. **F. LUCAS**—Electric Light for Lighthouses.

No. 4.—**E. MERCADIER**—Telemicrophonic Apparatus. **R. ARNOUX**—Mechanical and Electrical Efficiency of the last Creil Experiments.

No. 7.—**A. RENARD**—Electrolysis of Salts.

No. 9.—**LEDEBOER**—Dead-Beat Galvanometer of Deprez-d'Arsonval. **H. WILD**—Relation between Magnetic Changes and the Sun.

(*La Lumière Electrique, Vol.* 19, 1886.)

No. 1.—**B. MARINOVITCH**—The Button Telephone. **C. RECHNIEWSKI**—Study of Dynamo Machines. **C. DECHARME**—Application of Electricity to the Determination of the Weight of a Body. **G. BRACCHI**—Use of Iron and Copper Wires for Quick Transmission.

No. 2.—**G. RICHARD**—Some Constructive Details of Dynamos. **A. v. MEYDEN**—Calculation of Electrical Conductors. **E. DIEUDONNÉ**—Electro-Megaloscopy.

No. 3.—**J. MOUTIER**—Thermo-electric Currents. **G. RICHARD**—Ignition of Gas Engines by Electricity. **A. MINET**—Study of Galvanometers. **E. DIEUDONNÉ**—Tests of Submarine Cables.

No. 4.—**J. MOUTIER**—Faraday's Law. **G. PLANTÉ**—Effects of the Quantity Rheostatic Machine. **C. DECHARME**—Analogies between Electric and Hydro-dynamic Effects. **E. H. CADIOT**—Poste-Manville's Electric Regulator. **L. PALMIERI**—A New Experiment showing that there is a Production of Electricity when Vapour condenses into Water **E. GIMÉ**—Formation of Hypochlorites by Electrolysis. *Anon.*—Use of Springs in Polarised Telegraphic Apparatus.

No. 5.—**A. GRAY**—Methods of Absolute Measurement. **E. DIEUDONNÉ**—Condensation of Smoke by Electricity. **G. RICHARD**—Some Recent Telephonic Apparatus. **J. BOURDIN**—Apparatus for Microscopic Photography. **DUHEM**—Ampère's Law. **PASQUALINI and ROITI**—Continuous Observations of Atmospheric Electricity.

No. 6.—**G. COLOMBO**—Central Station at Milan. **F. GÉRALDY**—Theory of the Telephone. **G. RICHARD**—Electric Gun of Symes and Maxim. **J. BOURDIN**—Improvements in the Manufacture of Glow Lamps.

No. 7.—**C. DECHARME**—Application of Electricity to the Study of the Spontaneous Movements of Liquids in Capillary Tubes. **E. DIEUDONNÉ**—Earth Currents on Submarine Cables.

No. 8.—**G. RICHARD**—Electric Lighting of Trains. **B. MARINOVITCH**—Use of the Telephone over Great Distances. **A. TANNER**—Electrical Fusion. **P. CLEMENCEAU**—What is Electricity?

No. 9.—**A. GRAY**—Methods of Absolute Measurement. **C. DECHARME**—Application of Electricity to the Study of the Spontaneous Movements of Liquids in Capillary Tubes. **G. RICHARD**—Some Constructive Details of Dynamos. **B. MARINOVITCH**—Removal of Scale from Boilers by Electricity.

No. 10.—**E. MEYLAN**—Steno-Telegraphy. **LEBLANC**—Part played by Surface Tension in Electrical Phenomena. **C. DECHARME**—Application of Electricity to the Study of the Spontaneous Movements of Liquids in Capillary Tubes.

(*L'Electricien*, 1886.)

No. 142.—**G. ROUX**—Calibration of Voltmeters.

No. 144.—**D. MACNAB**—The Nature of Magnetism. *Anon.*—Button Telephone of Barbier.

No. 145.—**R. ARNOUX**—Similar Dynamo Machines. **D. MACNAB**—The Nature of Magnetism.

No. 146.—**L. DAFLON**—M. Fournier's New Magnetometer for Measuring H.

No. 147.—**D. MACNAB**—The Nature of Magnetism.

No. 148.—**L. GREZEL**—Metallic Depolarisation. **D. MACNAB**—The Nature of Magnetism.

No. 151.—**L. CHENUT**—Steno-Telegraphy.

No. 153.—**E. HOSPITALIER**—Circulating Batteries.

No. 154.—**E. HOSPITALIER**—Circulating Batteries.

(*Journal Télégraphique de Berne*, 1886.)

No. 1.—**ROTHEN**—Kölzer's System of Translation (*continued*). **Dr. TÖBLER**—Vianissi's New Method of Duplex Transmission.

No. 2.—**DELFIEU**—Fire-Damp Alarm. **SACK**—Automatic Bell for the Hughes Apparatus.

No. 3.—**ROTHEN**—Study of Telephony (1st part). **VIANISSI**—Note on Dr. Töbler's Article in No. 1.

(*Centralblatt für Elektrotechnik*, 1886.)

No. 1.—*Anon.*—Some Uses of the Zipernowsky-Déri Transformers. **Dr. M. KRIEG**—New Patent Arc Lamp. **E. LEYDT**—Observations on Lightning Flashes.

No. 2.—**J. KESSLER**—Measurement of H.

No. 3.—**Dr. M. ASCOLI**—Method of Electrical Calibration of a Wire.

No. 4.—**F. KOHLRAUSCH**—Simple Absolute Current Measurer for Weak Currents.

No. 5.—**W. PEUCKERT**—Transformation of Heat into Electrical Energy, and its Cost with Batteries, Thermopiles, and Dynamos. *Anon.*—Magneto-electric Call with Switch for Use with several Stations on One Line. **UPPENBORN**—Magnetic Speed Indicator.

No. 6.—*Anon.*—Improvements in Ader's Telephones. **W. PEUCKERT**—Calculation of Electro-Magnets for Compound Dynamos. **A. WINKLER**—Relation of the Atomic Motions in Radiant Heat and in Electric Currents. **M. BAUMGARDT**—Method of Testing for Contact between Two Conductors.

(*Elektrotechnische Zeitschrift*, 1886.)

March.—**Dr. KRIEG**—New Formulæ for Electro-Magnetism. **E. ZETSCHE**—Translation with Estienne's Duplex Inker. *Anon.*—J. Ebel's Cable Relay and Inker. **R. v. FISCHER-TREUENFELD**—Spanish Military Telegraphs. **A. PRASCH**—Use of Railway Telegraph Lines for Signal Purposes. **L. KOHLFÜRST**—Schwatzkopff's Safety Valve for Boilers. *Anon.*—Sombart's Speed Registering Apparatus. **A. WEINHOLD**—Equation of the Dynamo with Series and with Shunt Winding. **BÜHLMANN**—Resistance of the Electric Arc. *Anon.*—Use of a Telephone System of Wires for Fire Alarms. *Anon.*—v. Hefner-Alteneck's Unit Lamp. *Anon.*—Scharnweber's Arc Lamp.

(*Zeitschrift für Elektrotechnik*, 1886.)

No. 1.—**Dr. A. v. WALTENHOFEN**—Examples of the Use of the Law of the Electro-Magnet in Practice. **J. SACK**—Electric Clocks. **J. BAUMANN**—Working of Town Telephone Systems.

No. 2.—**W. PEUCKERT**—Calculation of the Electro-Magnets in Compound Dynamos. **KAREIS**—v. Rysselberghe's System of Long-distance Telephony. **Dr. H. HAMMERL**—Behaviour of certain Ring Magnets. **J. BAUMANN**—Working of Town Telephone Systems.

No. 3.—**Dr. A. v. WALTENHOFEN**—Siemens and Halske's Torsion Galvanometer. **G. PLANTÉ**—Action of the Current of the Rheostatic Machine. **R. v. FISCHER-TREUENFELD**—Military Telegraphs. **ROSS**—Prof. Weber's Photometer. **GRAVIER**—Improvements in Dynamo and Magneto Machines. **J. ZACHARIAS**—Use of Electricity for Motive Power.

JOURNAL

OF THE

SOCIETY OF

Telegraph-Engineers and Electricians.

Founded 1871. *Incorporated* 1883.

VOL. XV. 1886. No. 62.

The One Hundred and Fifty-sixth Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, May 13th, 1886—Professor D. E. HUGHES, F.R.S., President, in the Chair.

The minutes of the previous meeting were read and approved.

The names of new candidates were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Benjamin Duff.	William Standford.
James Jeffery.	Thomas J. Wilmot.

From the class of Students to that of Associates—

Oswald Haes.

The SECRETARY reported that in consequence of the steps which the Council had, with the approval of the members, taken on a previous occasion with reference to the Electric Lighting Act of 1882, they had thought it desirable that some action should be taken by the Society in regard to the Electric Lighting

Act Amendment Bills now before Parliament, and accordingly the following petition had been presented in the name of the Society:—

In the House of Lords.
Session 1886.

THE ELECTRIC LIGHTING ACT (1882) AMENDMENT (No. 3) BILL.

PETITION AGAINST.

To the RIGHT HONOURABLE the LORDS SPIRITUAL and TEMPORAL, in PARLIAMENT ASSEMBLED.

The most Humble Petition of THE SOCIETY OF TELEGRAPH-ENGINEERS AND ELECTRICIANS, incorporated "to promote the general advancement of Electrical and Telegraphic Science and its applications,"

SHEWETH:—

1.—That in the year 1882 an Act of Parliament was passed to apply to all Provisional Orders or Acts relative to the distribution of electricity for lighting and other purposes.

2.—That by Section 27 of the said Act it was enacted that at the expiration of twenty-one years, or such shorter period as might be provided in the Special Act, and within six months after the expiration of every subsequent period of seven years, or such shorter period as might be provided in the Special Act, any local authority within whose jurisdiction the area of the undertaking, or any part thereof, was situated, might require the undertakers to sell their undertaking, or part thereof, upon the terms of paying the then value of all lands, buildings, works, materials, and plant suitable to and used for the purposes of their undertaking, and in the event of non-agreement the price was to be determined by arbitration; but the arbitrator was forbidden to allow any payment in respect of compulsory purchase, or of good-

will, or of any profits which may, or might have been, or be made from the undertaking or of any similar considerations.

3.—That your Petitioners comprise, among their members, nearly every Electrician and Electrical Engineer of eminence in the kingdom, as well as a very large number of persons engaged in the manufacture and preparation of the various apparatus and material required for the production and distribution of electricity for lighting and other purposes.

4.—That your Petitioners believe the afore-mentioned Clause 27 of the Act 1882 has materially retarded the development of Electric Lighting in this country, inasmuch as neither capitalists nor the public will embark their capital in any undertaking subjected to such conditions as those imposed by the said Clause, which would render them liable not only to be deprived of the benefits of their enterprise almost as soon as it began to bear fruit, but would compel them to dispose of it, not at a fair valuation as a going concern, but at a price which would only yield them a small portion of the capital originally invested by them in it.

5.—That there are now before your Lordships' House three Bills, Numbers 1, 2, and 3, each of which purports to be an Amendment of "The Electric Lighting Act, 1882."

6.—That Number 3 Bill, brought in by Lord Houghton, does not vary the Act of 1882 except by extending the prescribed time before the compulsory right of purchase would arise, from twenty-one years to thirty years, with a further period of twelve years, should the local authority agree, and by the extension of the recurrent periods of option from seven to ten years.

Your Petitioners therefore most humbly pray your Lordships that the said Electric Lighting Act (1882) Amendment Bill No. 3, or any other Bill for the Amendment of the Electric Lighting Act (1882) which does not place Electric Light Undertakers on a similar footing to that of undertakers of other industrial enterprises, may not pass into law, and that this Petition may be referred to the Committee of

your Right Honourable House, to whom the Electric Lighting Act (1882) Amendment Bills have been referred, or that such other relief may be given to your Petitioners on the premises as your Lordships shall deem meet.

And your Petitioners will ever pray, &c.

Signed on behalf and by order of the Society of Telegraph-Engineers and Electricians.

(Signed) D. E. HUGHES,
President.

(Signed) F. H. WEBB,
Secretary.

The Meeting signified approval.

The PRESIDENT: I have now the pleasure of calling upon Mr. Preece to read his paper on "Long-distance Telephony." It is a subject of the utmost importance.

LONG-DISTANCE TELEPHONY.

By W. H. PREECE, F.R.S., Past-President.

I am always ready to obey the commands of our President, but on this occasion I regret to say that I cannot. It is quite impossible for me to read the paper, for the simple reason that the paper is not written; and I regret to say that during the past week I have been suffering from an accident to my eyes, which has prevented me either from reading or from writing, and therefore, if there is a little want of order or method in the paper that I am supposed to be reading to you, I must only crave your kind indulgence.

I had some difficulty in selecting a title for the subject that I am going to bring before you. "Long-distance Telephony" conveys the notion that I am going to speak of the art of telephoning to great distances; but the subject has two branches, long-distance telephony embracing the idea of how far we can telephone, and also long-distance telephony indicating how much we can transmit to distant places that can be considered commercially practicable. It is with this last question that I

intend to occupy myself mainly; it is that branch of telephone business that in England is called "trunk wire working;" it is the connection of town and town, as distinguished from that system of local telephones or connection between subscriber and exchange. In England, I say, it is called "trunk wire working;" in America it is called "extra-territorial working"—I presume from the fact that the Bell Telephone Company, who control the patents in that country, assigned certain territories to different local companies, and when these local companies transmit their business beyond their own territories they enter into that class of business that is called extra-territorial. Another term also very largely used in America is "toll line working;" *i.e.*, communication between town and town and place and place which is paid for by tolls per message, and not by annual subscription such as usually occurs in local exchanges. In Belgium the two modes of working are defined as "local telephony" and "inter-urban telephony," and I think that "inter-urban" is a very good term indeed to apply to this system of working to distinguish it from mere exchange or local working.

The main question that I want to introduce to you is, How far have improvements in telephones rendered this inter-urban telephony practicable, and how far can it be really considered as commercially successful?

The improvements in telephones during the last few years have not been very marked. There has been no single receiver of any sort or kind that can be said to be an improvement on the original receiver as brought out by Mr. Bell, and as brought over by me for the first time in the year 1877. There has been scarcely any improvement on the microphone transmitter as brought out by our friend the President in the chair. In fact, all the so-called improvements that have been made have simply been new tunes played upon the same old strings, and those strings may be called Bell, Edison, and Hughes. It is perfectly true that there have been modifications of transmitters that have reproduced, under certain circumstances, greater and better effects. It is quite true that Mr. Edison in his first transmitter started something totally new; he

secured a patent for it, he has upheld that patent for it, and I think deservedly so, but the curious thing is this, that none of the transmitters that have rendered telephones practical instruments have been based on Mr. Edison's system, but they have been based upon the microphone that was first brought before an audience in this very room, viz., the Hughes microphone. Hunnings started a modification—it was certainly a considerable modification, and it produced great results—and the same principle is brought out over and over again in different forms and under different names by different people. An excellent form of Hunnings' transmitter was produced by Mr. Moseley, of Manchester. Lately the same thing has been brought out under a different name in Paris; it is known as the "Berthon transmitter." New transmitters, in fact, at one time came out as thick as thieves, and scarcely a week passed without some rampant and excited inventor coming to my office with some grand transmitter that was going to produce the most extraordinary and wonderful results, such as that we were going to talk across the Atlantic, we were going to put every capital in Europe in communication with each other, and there was to be no more difficulty in speaking between New York and San Francisco than there was in talking between the City of London and Westminster. However, all these things have quietly dropped out of existence. But the cry is "Still they come," for during the last two days I have had no less than two quite fresh inventions really very similar to things that I have seen before.

I am not going to say much about accessories. Switches, bells, and annunciators have undergone vast and wonderful improvements, but they do not affect my question to-night; they would occupy too much time, and therefore I propose to leave them, probably for some future occasion. But I do want, before I go into the subject, just to draw a little comparison between the development of the telephone interest in the United States of America and its development in this country. In the summer of 1877, when I was in America, there was not a single telephone out on hire or used commercially for any purpose whatever; there was therefore not one single exchange. But towards the end of

the year there were no less than 780 telephone instruments commercially in use. In 1880 this number had increased to 60,800, and there were 100 distinct exchanges at work in that country. In 1883 there were 249,700 instruments; and at the end of 1885 there were 325,574 instruments in use, and 782 exchanges.

Now let us take Canada, which, telegraphically, is connected with America, and may be looked upon in a telegraphic sense as a part and parcel of America. In Canada, with a population of, I think, something over 4,000,000, they had 18,000 telephones at work at the end of 1885. Well, now, what was it in England? In England at the end of 1885 there were only 13,000 subscribers! New York, Brooklyn, Jersey City, and a few of the places round about New York, together utilise more telephones than the whole of the United Kingdom. Chicago has 3,630 subscribers connected with exchanges; Philadelphia, 2,310; Cincinnati, 2,535. Well, when we come to Europe, we have not to go to London for the first place on that Continent; the head of the list amongst cities employing telephones in Europe is Berlin, which has 4,248 subscribers, as against 4,193 in London, and 4,054 in Paris. In Stockholm, which is a small place compared to Paris and London, there are 3,825 subscribers. In Rome, which is in the southern climes where people are supposed to lead rather a comfortable, lazy, and *dolce far niente* kind of life, they have 2,054 telephone subscribers. And so we have to come down through several Continental cities before we come to our large centres like Manchester, with 1,171; Liverpool, 1,169; Glasgow, 1,041. These figures give us clear indications that from some cause or other the development of the telephone in England has not been so brilliant or so successful as some of us could wish.

Mr. EDWARD BRIGHT: The charges.

Mr. W. H. PREECE: It is not a question of charges, which, as a matter of fact, are higher in America than in England.

Mr. GEORGE A. MASON: I can verify that.

Mr. W. H. PREECE: The charges in America are much greater than they are in this country, but we have nothing to do with charges to-night, neither have we anything to do with the

restrictions, that are also greater in America, but we have something to do with one or two other points that I shall bring before you before I finish my subject.

Firstly, as to mere distance speaking. In 1877, when I brought the first telephones over, as an experiment we spoke from Dartmouth to Guernsey—a distance close upon 60 miles—through the cable, with clearness and distinctness. A little later I spoke between Holyhead and Dublin—a distance of more than 60 miles—and I can very well remember that our poor old friend Sanger, who is now dead and gone, and was at the other end of the wire, when I asked him if he could hear my voice he replied, "Yes, and I can smell your cigar." I was anxious at that time to pursue this subject of the distance through which we could speak over cables. Messrs. Clark, Muirhead, & Co. had then some "false cables" that had been made, I think, for duplexing the Direct United States Cable, and the result of experiments on this false cable went to show that it was quite impossible, for practical purposes, to speak through a cable of the dimensions of the Atlantic Cable to a greater distance than 20 miles; and, curiously enough, at a meeting of the British Association—I think it was at Aberdeen last year, or the year before—Lord Rayleigh read a paper in which he showed by mathematical calculation that it would be impossible to communicate through a cable of the pattern of the Atlantic Cable to a greater distance than 20 miles. In Persia Mr. Taplin succeeded in speaking between Tabreez and Tiflis—a distance of 390 miles; in India Mr. Johnson spoke between two places—I am not sure as to the names, but the distance was 500 miles. In America they have frequently talked to a distance of 1,000 miles; and to-night we have the great pleasure of the company here of a gentleman who has been nominated this evening as a foreign member of the Society—Mr. Van Rysselberghe—who will himself narrate some recent experiments of his in America where conversation has been carried on by his system to a greater distance than even 1,000 miles.

This question of speaking to a distance is not a question of apparatus. Inventions that are constantly coming over to this country called long-distance telephones, based on supposed

novelties and on new transmitters, are practically useless, for the difficulty in speaking to a distance is not a difficulty with apparatus at all; it is a difficulty with the conductor, and with its environment. We have disturbances of various kinds to deal with: we have induction—electro-magnetic and electrostatic; we have resistance, and its influence in combination with induction in producing what we call electro-magnetic inertia; we have disturbances due from mutual induction—the energy lost in contiguous wires from a wire conveying telephonic currents; we have disturbances due from earth currents passing over the crust of the earth that are taken up by the telephone circuits; we have disturbances due to the wires themselves swinging in the magnetic field of the earth; we have disturbances due to atmospheric agencies—to atmospheric currents that enter the wire, and which are sometimes of a very irregular character; we have disturbances in towns due to the contiguity of telegraphic circuits and of electric light circuits (electric light circuits are likely to be a serious bugbear to the telephone interest); and, again, disturbances are due to the currents used for tramways, for the transmission of power, and for other purposes. All these disturbances cause a blurring or a muffling of the sounds reproduced. The sibilants are the first to disappear; the fine delicate currents that produce the "s" and "c" sounds are extremely minute, and they are rapidly swallowed up by electrostatic induction, and also by mutual induction. As these disturbances increase the volume of sound diminishes; the tone is thus lowered, the articulation entirely disappears, and there comes through nothing but a blurring sound. All this can take place on a short circuit just as well as it can through a long circuit, and we have in the Post Office a test circuit that only extends from the Post Office in St. Martin's-le-Grand to our stores at Gloucester Road, Regent's Park, and I have never yet succeeded in finding an inventor, or in finding an instrument, that will speak over this short distance of four miles, simply because the wire passes through a neighbourhood where it is subject to most of these disturbances in their most aggravated form. I have conducted at different times very careful experiments to solve this question of distance speaking, and on wires from which

these disturbances have been eliminated. It is a very easy thing to eliminate the effect of these exterior disturbances as far as sounds are concerned; it is perfectly practical and perfectly easy to establish a telephone circuit that shall have no audible disturbance upon it whatever. There are few telephone circuits in this country that have been put up by the Post Office that are not put up as a metallic circuit. The metallic circuit, in the majority of cases, is a twisted wire, and I do not think there is such a telephone circuit under the charge of the Post Office on which the slightest disturbance of any sort or kind is to be heard. But, notwithstanding that, we cannot speak to distances; for instance, at Newcastle-on-Tyne the whole, or nearly the whole, system is underground, and in 1882 we laid down some fine wires—"Henley's twin wires" they were called, and the wires were very small and were very near to each other—and there the limit obtained by the most careful experiment was a distance of only eight miles; that is, it was practically and commercially possible to communicate through a distance of only eight miles. In 1884 we found that this Henley's wire was a failure—the insulation failed from some cause or other—and we employed in its place gutta-percha of rather a small size, and then we found, with better insulation and larger wire, the limit was increased to twelve miles; and now, in the year 1886, with the character of cable we use, which is a cable consisting of four gutta-percha wires twisted together, we obtain a limit of 20 miles. These four-wire cables form the angles of a parallelogram, and the diagonal wires of the parallelogram are connected together in circuit. I have spoken with ease and comfort to a distance of 39 miles underground; but, although it is possible to do so to that extent, it is not advisable, with the form of cable that we at present use, to speak to a greater distance than 20 miles.

In order to test this question for overhead wires, the Post Office went to the expense of running four wires from London through Towcester, Stafford, Nantwich, and Warrington, where they branched off to Liverpool and Manchester. They were No. 8 gauge of iron, and weighed 400 lbs. each to the mile, giving a resistance of about 12 ohms per mile. These four wires were

erected on the twist principle, so that all disturbance from mutual induction or from the effect of contiguous wires was entirely eliminated, and between London and Warrington there was not a sound of any sort or kind to be heard; outside disturbances were entirely eliminated; but we found that the practical distance to which speech could be conveyed was 100 miles. At a distance of 150 miles the speech was good, but rather grave. There was loss of sibilant sounds and those tones which are necessary to carry on conversation for business purposes; at 170 miles conversation was still possible, though not practical; and at 200 miles nothing was heard but low rumbling sounds. This happened, unfortunately, to be a line constructed of iron wire. The effects of self-induction, which have been so prominently before us since our President's address, and recent experiments on copper wires, as well as some other valuable experiments that Mr. Van Rysselberghe will bring before you, have shown unmistakably that if these four wires between London and Liverpool and Manchester had been of copper, then speech would certainly have been quite possible and practical.

Now I want to say a word about this inter-urban or trunk wire working. I was in America in 1884, and one of my duties there was to investigate very carefully and fully the working of the telephonic system in that country. Last year I went to Belgium with the expressed object and purpose of investigating the working of the system inaugurated by Mr. Van Rysselberghe there. I will give the result of both of those visits. First, as regards the United States. In the United States the inter-urban telephone system has been carried out to a large extent, although not nearly to the same large extent as their local telephone system. In the States there are 31,395 miles of poles and 42,461 miles of wire erected for this purpose. Thus it will be seen that the difference between the miles of poles and miles of wire is very small, hence the great majority of those trunk wires in America are single wires on single lines of poles, and therefore they ought to be free from disturbance. The system adopted is what I have just termed the "toll system." A person can go to any place, he can communicate with any other

place on that system by payment of a toll, and the toll is 25 cents (one shilling) for five minutes' conversation. It is found that the average time that a conversation takes is about two minutes, but taking everything into consideration—time lost in calling, and so on—it generally occupies five minutes for a call. The total earnings on all these trunk wires during the last year was 538,740 dollars, which comes out at about 12·6 dollars per mile of wire. The greatest distance that I spoke over was between Chicago and Milwaukee—95 miles—but the speaking was not good. Between Chicago and Michigan City—65 miles—speaking was very much better, the reason for the difference being that the Milwaukee wire was of iron and the Michigan City wire was of copper. I spoke between New York and Boston—350 miles—with very great clearness indeed, and that was owing to the fact that between those two places two copper wires had been erected and used as a metallic circuit. I do not think that that circuit has ever been opened to the public, for it was found that it had been erected along a most unfavourable route; contacts were frequent and the maintenance was difficult, but while the circuit was intact there was no difficulty whatever in working between those two towns. Between New York and Philadelphia—90 miles—and between Milwaukee and Oshkosh—110 miles—practical speaking is successful. A very curious plan has been adopted for raising capital to erect these trunk lines. The representatives of the company arrive at a place and express their readiness to put it in communication with the nearest exchange provided the inhabitants will take a sufficient number of toll tickets to raise 50 dollars per mile. No difficulty is found in getting the proposal accepted; the people willingly subscribe 50 dollars for a set of toll tickets, and when they have received the tickets they very soon use them up, and the practice therefore incites the people to the use of the telephone, and the result is satisfactory to the telephone company in two respects. Although this practice has to a certain extent been successful in attracting capital, it cannot be said that the trunk system in America has been altogether successful. There is no doubt that the difficulty in speaking over long distances has retarded the use of the system, and the result is that the average

number of messages per day is only 30 per circuit, which shows that with an average income of 12 dollars per mile, and with a cost of maintenance that comes very nearly to the same amount, it cannot possibly pay the promoters to put up these trunk wire systems alone. The value of the trunk wire system is not that it pays, but that it attracts subscribers to the local exchanges, and thereby indirectly the system pays. However, there is no doubt that this toll line and inter-urban system has a field of its own, and it only requires development in England to meet with a certain amount of success. Its development in England is perhaps a little more satisfactory than the local exchange system. The United Telephone Company—who virtually control, as we all know, the telephone business of this country, and to a certain extent manage it—has only one real trunk wire system, and that is a circuit from London to Brighton. But the Lancashire and Cheshire Telephone Company—a much more enterprising concern—has covered the whole of Lancashire with a complete network of trunk wires; all their principal towns — Liverpool, Manchester, Warrington, Wigan, Blackburn, Preston, Blackpool, Burnley, Todmorden, Rochdale, Oldham, Staleybridge, Stockport, Widnes, Runcorn, Chester, Birkenhead—are connected together by trunk wires. These trunk wires are of copper; they are put up in pairs, although for some inscrutable reason up to the present moment they have not been worked as a double-wire or metallic circuit, and, except in one or two instances, they are content to use them as single-wire circuits; and the result is such that I have spoken from a suburb of Manchester to a suburb of Liverpool (I think it was New Brighton) on the Mersey—a total distance of nearly 60 miles—with great ease and comfort. But that was in the evening. It is a very difficult thing indeed to speak through in the daytime, for we all know that then the telegraphs are at work, and the single trunk wire parallel system is not successful under such conditions, and is only useful in attracting subscribers to local exchanges.

The National Telephone Company is also an enterprising concern. It has a good many trunk wires connecting the principal cities in Scotland, viz., Glasgow, Edinburgh, Paisley, Greenock,

and—I am not quite sure, but I think Dundee is on the system; they are all connected together, and a very fair business is done. There are 27 circuits, the average length of each is 35 miles, and the average number of messages per circuit is about the same.

But the most complete system of this inter-urban communication has been carried out in Belgium. Belgium differs from England in this, that there the whole concern is under one management; the Government controls everything. The Belgian Government have very wisely placed the working of the telephone system in the hands of the companies in the towns, and they have taken under their own wing the working of the trunk wire system. They have adopted the Van Rysselberghe system, and, though I scarcely like to anticipate what he may say about it, I think it is only right for me to mention, in the first place, that the pith of Mr. Van Rysselberghe's system is this, that instead of attempting to get over the difficulty of working long distances by inventing new transmitters, or by trying to remove the effect of induction from taking place at all—that is, instead of playing with the secondary currents—he goes to the primary currents, and so reduces their form that he practically renders them innocuous. He found that, if a current be represented by a curve, then the more rapid the rise of the curve and the more rapid its fall—the more sudden its action—the higher would be the secondary effect on the listening telephone. He will, I dare say, explain how he arrived at it, but he found that if he inserted into the primary circuit either a condenser or an electro-magnet, or a combination of a condenser and electro-magnet—such an effect as would cause the rise to come gradually and its fall slowly—then the effect on the contiguous telephone would entirely disappear. In a Hughes circuit, for instance, between Brussels and Ostend, which produced enormous disturbance and loud pattering sounds in a contiguous telephone, if an electro-magnet were inserted then all these sounds would disappear. Mr. Van Rysselberghe noticed that on a wire between London and Brussels, while the currents going from Brussels to London produced very loud and very intense sounds, the currents coming from London produced no effect at all. At the present moment every single circuit

in Belgium is armed with the anti-inductors of Van Rysselberghe, and the result is that there is no disturbance whatever upon the telephones; more than that, it is not necessary to put up telephone wires at all, for the wires that are used for telegraphic purposes can be employed, and speech is now conducted between Brussels and Antwerp, Charleroi, Liege, and various other places, on telegraph circuits by means of the Van Rysselberghe system. The diagram [*Fig.* 1] shows the connections of the arrangement.

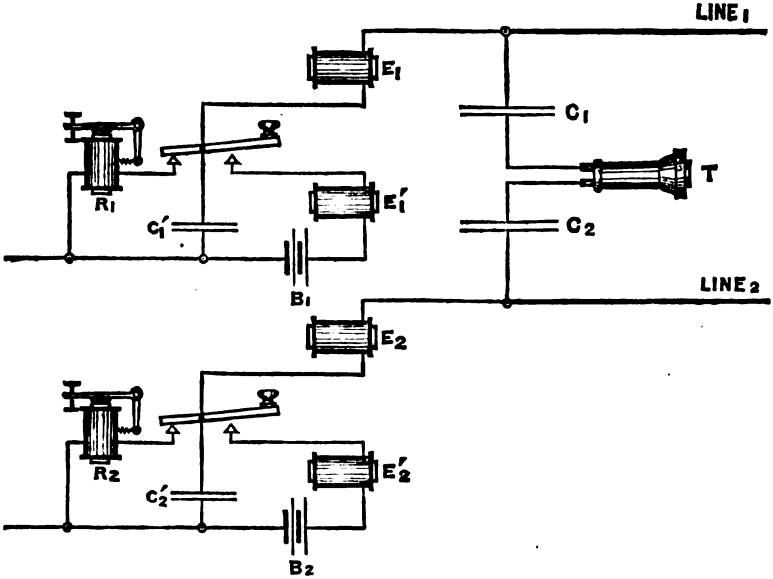


Fig. 1.

From the Morse instrument key the current passes through the anti-inductor to the relay, and then to earth; the battery circuit has also an anti-inductor upon it, as well as a condenser, as shown. The telephone is connected in bridge with two condensers, and the result is that no current used for telegraph purposes will pass through the bridge, but any telephone current coming from the distant end affects *this* condenser, because for telephone purposes there is a metallic circuit, while for telegraph purposes there is an earth circuit; there are two earth circuits for telegraph purposes, and one metallic circuit for telephone purposes. The telephone currents are induced currents; they are taken up by the condensers, and

the speech at Antwerp is reproduced at Brussels upon this telephone by the action of these two condensers. So we have for each circuit two anti-inductors and a condenser. Throughout Belgium this combination of anti-inductors and condensers has been adopted, with the result that all busy centres in Belgium are connected together, and inter-urban communication is there practical and feasible. The charge is one franc for five minutes' conversation. I ought to say that the system is fairly patronised; I do not say that it is successfully patronised: it is quite in its infancy at present. Like the experience in America and here, the trunk wire working is not at present commercially successful, but if it is likely to be successful anywhere it will be in Belgium—a place where there are large centres and short distances, where there is one power and no rival or antagonistic interests at work. At my visit the number of messages was small—between Brussels and Antwerp it only averaged nine per day per circuit—but Mr. Van Rysselberghe will doubtless be able to tell us that the number has increased considerably since that date.

Now comes the question—and it is the question that I had to carefully and particularly inquire into—Why cannot we introduce such an apparently estimable system in England? In the first place, it must be remembered that every circuit has to be armed with an anti-inductor; the currents have to be retarded, and the mere act of retarding currents, while having no apparent influence on the working of Morse circuits; worked at the rate of from 15 to 20 words a minute, or on the Hughes instruments, worked at a higher rate, has a very serious retarding influence on the system so much in vogue in England—that is, the Wheatstone automatic system. We are now working the automatic system habitually at 300 words a minute. We have worked it up to 400 words a minute, and we could do so to-morrow if there were a necessity for it, but there is no such necessity; 300 words keeps down the business, and 300 words per minute is now our normal speed for all our news purposes. If we were to put into our Wheatstone circuits these anti-inductors,our speed would run down at once to something under 150 words a minute, but we cannot afford to deteriorate our telegraph working for the sake of any

telephone system at the present day. Again—I am giving my reasons rather fully because Mr. Van Rysselberghe is here, and he will have an opportunity, perhaps, of replying to some of them—the system involves the use of numerous pieces of apparatus; every circuit (as will be seen by the diagram) will require three distinct pieces of apparatus, and the number of circuits in England very considerably exceeds those in Belgium. In Brussels the number of circuits is 133; in London, converging on our Central Telegraph Station, there are 940; in Manchester, 202; in Liverpool, 168; Glasgow, 154. But apart from the necessity for arming all these circuits, we have in England the railway circuits to deal with. Every railway company has a telegraph system of its own, with an enormous number of instruments, and every one of these would require to be armed. Further, there are cable companies that have wires going through the country to various towns, and cable stations forming systems of their own; while the telephone interest would also have to be regarded; and the result is that while the capital required to fit up the apparatus in England would be very great, and while the rival interests are very numerous, and some of them impossible to move, it does not seem worth while at the present moment to introduce such a system with so little chance of it being profitable, especially when the work can be carried out very much better at a very much less cost by putting up special trunk wires for special telephonic working.

In France the Van Rysselberghe system has been looked upon with a rather more favourable eye. I do not doubt the practicability of the system; I do not raise a question about that, and believe it to be quite practicable. In France it has been experimented upon and circuits established between Paris and Rheims—135 miles—and between Rouen and Havre; while in other parts of the Continent circuits have been established, as between Berlin and Halle, Berlin and Breslau, Vienna and Brün, and between various other places; so that the system certainly has a prospect of receiving a very fair trial on the Continent. It was my intention to say something about what had been done with this system in America, but I will leave that to Mr. Van Rysselberghe. Dr. Rosebrugh and Mr. Black have been experimenting

in the matter, but they seem to have availed themselves a great deal of the experience on this side of the water, but up to the present moment I have not learned that they have met with any very great success. It was also my intention to say something about Captain Cardew's system of working telegraphs with telephone instruments, which system we heard a great deal about when General Webber spoke of the experiences in Egypt; but as it is purely a telegraph matter, and is coming before the Society at the next meeting, I will pass it over.

I will now refer to what the Post Office has done in extending this system of working in England. I do not think that in any country—certainly in any country that I have visited—has the telephone business been more thoroughly, more successfully, or more perfectly developed than it has been in the neighbourhood of Newcastle-on-Tyne. Newcastle-on-Tyne is the centre of a very busy neighbourhood. North and South Shields, Sunderland, Middlesbrough, Stockton, Darlington, and other places, are all in intimate communication with it. Every one of these places has its own local exchange, and all these local exchanges are connected together by trunk telephone wires. The system owes its present perfection and the admirable way in which it is worked to Mr. A. W. Heaviside, who also is here to-night. The system consists of double wires everywhere, and no disturbance exists of any sort or kind. Conversation can be had between any of the towns I have mentioned in the district with great ease and perfection. This is due to the fact that we have introduced there a new mode of working called the "bridge method," and I mention it because we have here utilised in a very successful way that principle of self-induction that has formed the subject of discussion in this room so many evenings this session. The diagram before you [*Fig.* 2]

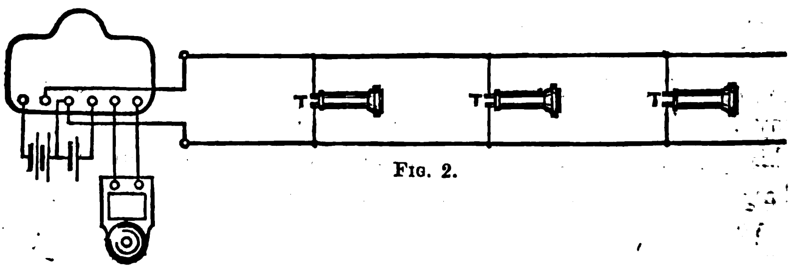


FIG. 2.

represents one end of a trunk wire working, say, from Newcastle to Darlington, through Stockton, West Hartlepool, and Middlesbrough. It is most desirable that telephones in such a trunk wire should always be available for calling or for attention at any moment, and therefore they must be connected up as shown. A steady current passing through will ring the bells at each station, and a concerted signal will indicate the particular station that is wanted. Suppose Newcastle wants Stockton: Newcastle calls Stockton, the indicator drops and shows that Newcastle calls him; the other stations in circuit observe the call, but know it is not for them; they simply put up their shutters and leave Stockton to communicate with Newcastle. Now, while these telephones in bridge are perfectly susceptible to action from a steady current, when rapid reversals (which the telephone currents are) are sent, then the indicators in these bridges, being specially constructed of a large mass of iron—high resistance with an iron sheath, in fact—contain so much self-induction that the currents passing through from Newcastle to Stockton have no influence whatever on the telephones at the intermediate places; in fact, telephone currents to telephones in bridge, as shown on the diagram, are absolutely negligible; the throttling action, as Lord Rayleigh calls it, is so high, the extra induction—the word for which we have had a little controversy here———.

Professor HUGHES: Resistance.

Mr. W. H. PREECE: The extra or hyper-resistance, as it might be called, checks all disturbance. There is something in these circuits beyond mere resistance; something is called into existence —it may be called self-induction, extra resistance, or throttling action—but the effect is, in working telephones on this bridge method, to really practically render the bridge at every station, but that to which you are working, as negligible, and you may leave it out of the question. The result is that between the places around Newcastle that I have mentioned, as also in South Wales, between Swansea, Cardiff, Newport, and along the valleys to Talywain, which speaks to Swansea—a distance of 80 miles—no difficulty is experienced in working trunk telephone lines. From Darlington to Newcastle—50 miles—absolutely no disturbance takes place, and the working is quite perfect.

Now I know, as a rule, that Government control is not liked, and anything that is done by Government officials is not appreciated. It is supposed that improvements are generally checked by this miserable Government espionage, but as a matter of fact the only real improvements that have been made in telephone working in this country have been made by the Post Office officials. We cannot congratulate ourselves very much in England on the development of this telephone business generally. The policy has been to crush out incipient opposition, not for the sake of furthering the business, but to put down impudent inventors; in fact, we may say that there has been "joy in heaven" over one poor sinner imprisoned, and there has been a good deal of "weeping and gnashing of teeth" whenever the guardian of the public interest—that is, the Post Office—has gained any victory over the telephone interest. Fortunately there is sunshine through the clouds; our patent laws do not allow patents to last for ever. The patents will sooner or later expire, and when they do expire I venture to think that we shall see in England as much development in telephone enterprise as we see in the United States.

The PRESIDENT: I have listened with a very great deal of pleasure to Mr. Preece's remarks, and I am sure we shall all be very glad to hear what Mr. Van Rysselberghe has to say, if he will favour us with his views upon the subject.

Professor Van Rysselberghe.

Prof. F. VAN RYSSELBERGHE: Gentlemen,—Many reasons prompt me to keep silent to-night, one being that I speak such poor English that I scarcely expect to be understood, but I would wish to offer my thanks for the kind invitation to address the meeting, and also to thank the Society for accepting my nomination to-night as a Foreign Member of the Society in which so many prominent electricians are to be found. At the same time, long-distance telephony is a subject so interesting to me that I hardly could keep silent if I would, but I am not at all prepared to speak fully upon the matter to-night. It is quite by accident, and only through the kind invitation of Mr. Preece, that I am before you this evening; but if the subject is of sufficient interest to the Society, I am quite willing to come over again on another occasion with instruments in order to illustrate by actual experiment the

principal features of the system. That being so, I will also on the same occasion demonstrate to you that the first inventor of simultaneous telegraphy and telephony over the same wire is one of your own countrymen—Cromwell Fleetwood Varley. I will also prove that the same Cromwell Fleetwood Varley was the inventor of the first actual, real, speaking telephone. I think he did not know it himself, but still he has described an instrument which I made according to his drawings, and which talks as well as any Bell instrument, and on the same principle, so really he was the inventor of the first speaking telephone. Professor Van Rysselberghe.

I will limit my remarks to-night to giving some information about experiments which I recently made in America. Those experiments were made for practical commercial purposes, and I guarantee that nothing which I say here is speculation based upon possibilities, but is the result of experiments made for the purpose of commercial business. We tried iron wires and copper wires of several descriptions and for various distances, and with iron wires it is quite impossible, as Mr. Preece has told us, to conduct commercial talking over a distance greater than, say, 150 miles, which will act very well. Up to 200 miles the result is good, but there is nothing special about it. We have found with iron wires that while on long distances the volume of sound is sufficient, the tone of the voice alters—everybody becomes bass; they are no longer tenor or baritone, but all bass—and the high notes become lost, the articulation disappears, and everybody, as it were, speaks through the nose, with a blurred effect. Experiments with copper wires came out with quite a different result. We tried No. 14 copper, No. 12 copper, and also the compound wires of the Postal Telegraph Company. The compound wires were of an iron or steel core of about 3 mm. thickness, and covered with copper up to a thickness of 1½ mm., making a total thickness of 6 mm., and equivalent to a copper conductor of 5 mm. With No. 14 copper good commercial talking was obtained up to 300 miles; it was possible to go to 500 miles, but 300 would be commercially serviceable. With No. 12 copper—a little larger than No. 14—we obtained very good results up to 700 miles; but when we came to the large compound wire which we tried between New York and

Professor Van Rysselberghe.

Chicago—a length of 1,010 miles—the result was tremendous. I spoke from New York, and when I called for the first time for my friend at Chicago the reply came in such a clear, strong, and loud sound that I could not believe myself; but there was no mistake—Chicago was there—and we called in everybody in Chicago in order to have it proved that we were speaking through over 1,000 miles. The best effect was obtained by holding the receiving telephone about two inches from the ear. The result was of a practical and commercial character, and every one present was of that opinion at the time. We could not obtain the speaking limit with these wires. Everybody was of opinion that conversation could be easily carried on over three times the distance available, or 3,000 miles. I think four times, or 4,000 miles, is possible; but I would guarantee, and take the responsibility, that practical working could be conducted over twice the distance, or 2,000 miles; there is no doubt about that. With No. 14 copper the limit of understanding is reached at 300 miles, while at 500 miles there was no longer possibility of commercial talking, the reason being simply that the voice was too weak; but up to the limit of perception by the human ear the voice is perfectly clear and distinct—no alteration at all. The voice of your interlocutor, and every syllable, even the "s," comes out perfectly clear; there is no mixing up, and no self-induction as in iron. When the "s" consonant (which is the most difficult to get by telephone) comes out clearly, every word will come out. I can say no more to-night about these experiments under the circumstances.

I quite agree with Mr. Preece that the conditions of telephony and telegraphy are quite different in this country from other countries; in fact, in each country one finds special conditions which have to be dealt with. But I hope that, in turn, Mr. Preece will agree with me that if some day long-distance telephony is developed in foreign countries, England should not keep behind.

From the results I made in America it is clear that in Europe international telephony is possible, and I hope to prove this very soon in Europe by putting up a telephonic exchange between Paris, Brussels, Rotterdam, and Amsterdam—a distance of 400 or

500 miles. There is no doubt that, taking copper wires of convenient size, this will be a perfect success as far as effect is concerned. Now, as far as business is concerned, will it pay? I think, certainly, yes, if necessary measures are taken. In reply to the question whether inter-urban or international exchange working will pay, I think we cannot base our calculations upon America, for the experience there is no guide. It is well known that at present in America there is a difficulty, not of a technical nature, but of the nature of an agreement between the Western Union Telegraph Company and the Bell Telephone Company, under which the Bell Company cannot, without the consent of the Western Union Company, put up telephone circuits for distances over ten miles. The Boston and New York line is ready, and could at once be put into operation, but the Western Union Company will not allow it. The agreement was for 19 years, and as long as that stands there will be no long-distance telephony in America. Therefore we cannot base our action upon the American experience, for it has not been tried except in those places where the telephone could not be of the slightest help to the telegraph. There is no question that the Western Union Company looks upon the telephone as a powerful competitor, which will reduce their business, and for some reason or another, in the very beginning of the telephone business in America, the Western Union Company was enabled to bind the Telephone Company in such a way that nothing could be done, however valuable, as far as long distance was concerned. Now in Belgium it pays; the Government has already recovered all expenses incurred on account of it. The mean average business done between Antwerp and Brussels alone is 150 communications per day; sometimes during Bourse hours it reaches 175 or 200, but regularly not less than 125 communications per day. Professor Van Rysselberghe.

Now, gentlemen, again I thank you very much for your kindness this evening, and upon the next opportunity that I have of addressing you I will have instruments with me in order to give you further particulars.

Professor SILVANUS P. THOMPSON: I am rather interested to hear of another original inventor of the telephone. There have Professor Thompson.

essor npson. been so many whose names have been mentioned for that object since the death of the man whose claim in his lifetime was never disputed, and there are so many whose claims are obviously very feeble, that I think it is not worth while to discuss whether one more makes any difference.

But I come to a scientific point upon which I have the misfortune to differ from Mr. Preece. I was a little surprised to find him say that this was not a question of a new or a better transmitter than that which is usually in vogue. My own impression is that it is very decidedly a question of a new and better transmitter. Our receivers are too sensitive; they pick up all sorts of sounds that stray in by one or other of those various intrusive causes of which we have heard, and they bring to our ears more than we want to hear. What we want to do is to employ a less sensitive receiver and a transmitter so powerful that it will drown out these noises. It may be remembered that some two years ago there was a second telephone exchange in operation in London —that exchange, I mean, which existed for some time under the management of the London and Globe Telephone Company— which was worked by means of Hunnings' transmitters. That exchange was worked through wires, not of iron, but of silica-bronze or phosphor-bronze. It was worked with receivers which were in direct circuit, containing electro-magnets excited by the line current, and which, constructed as they happened to be, were not quite so sensitive as the more ordinary pattern of a magneto receiver. Certainly for goodness of work and freedom from induction there was no comparison whatever between the working of that particular exchange and the ordinary working of the exchange which is the best thing we have got at present. We want a very much more powerful transmitter in order to simplify our working. When I say this I am not wishing to undervalue the other means that have been proposed to destroy those interfering causes. We want a transmitter that, among other things, will satisfactorily convey the sibilant sounds. These sounds are the first to die out, simply because of the influence of self-induction. The retardation that self-induction causes on every line, affects first those impulses which come most rapidly, and therefore affects most the

Professor Thompson.

sounds of highest pitch; and as the sibilants are the highest sounds in all the range of human speech, they are the very first to disappear when the self-induction is large and the resistance small. They may be kept up by getting the self-induction small and the resistance large, relatively. Here again I find myself unfortunately in conflict of opinion with Mr. Preece, who seems to think that it is necessary to keep down the resistance. I hold, on the contrary, that the best thing to do is to keep up the resistance by using thin conductors, such as silica-bronze or phosphor-bronze, at the same time keeping down self-induction by avoiding unnecessary turns in the coils and unnecessarily thick iron cores.

I may mention some experience in connection with another aspect of this question. I have experimented and have tried to find something that shall be more satisfactory than the ordinary pencil carbon that is used in the battery transmitters, such, for example, as the Blake and the Gower-Bell, and I find that there is one substance, or, rather, one class of substance, which for certain purposes is admirable, and is far better than carbon in its particular purpose; though, for certain other reasons, it may not always be advisable to use it. I refer to a product invented by a collaborator of mine—Mr. Jolin, of Bristol—made from copper and selenium, two metals. The copper, when properly treated with selenium, acquires a beautiful surface, and looks almost like polished steel. When this substance is used in any ordinary transmitter—take out the carbon button from a Blake transmitter, and put in a button of this substance—the ear at once perceives that the articulation is marvellously crisp and sharp, and that the sibilants come out with the most unusual goodness of articulation. But unfortunately there is this drawback, that the substance does not stand the damp in the same way that carbon does, and therefore, if you are likely to get your surface damp, you find that the selenium tends to oxidise, and you get local action at the points of contact.

Now let me refer to the matter of long-distance telephony and to the anti-induction devices. No one could appreciate more highly than I do, the great advances made by Mr. Van Rysselberghe in showing us how to utilise the retarding effects of

Professor Thompson.

self-induction. He has made a very remarkable use of the "time-constant" of self-induction. He has utilised the time-constant to retard the signals; he has smoothed out the electric waves so that, though they may cause the membranes of our telephones to move a little forward or a little backward when the telegraphic current is turned off or on, they do not come into sufficiently rapid oscillation to make the familiar nasty jarring sound in the ear. While I congratulate Mr. Van Rysselberghe on all that he has done in this respect, I want to point out that he has only carried further an important discovery already known. That discovery was originally made by two Canadian gentlemen whom Mr. Preece named. I think he said that Mr. Black and Dr. Rosebrugh had taken their ideas from this side of the water. I, on the contrary, am inclined to think that we on this side are indebted to them; for it was in 1878 that Mr. Black showed that one difficulty in long-distance telephoning could be effectually got over by putting a condenser in the circuit, as a bridge to any electro-magnet in the line [*illustrated by sketches on the board*]. Later—in 1879—the same two gentlemen introduced a method of telephoning on the Canadian telegraph lines by the use of two parallel telegraph wires, each of which was being used for telegraph signals: they united these two lines by bridges at each end, each bridge containing a condenser and the telephonic instruments [*illustrated by sketch on board*]. These very important discoveries which were brought forward by Black and Rosebrugh in 1878 and 1879 go very far towards solving the problem of simultaneous telephoning and telegraphing, at any rate so far as concerns the closed circuit system of working. They did one thing more at that date, thereby anticipating, unconsciously, that which has since been done far better by Mr. Van Rysselberghe. They connected their wires from the middle point between the two coils of the electro-magnet of the Morse instrument or relay, using one of the two coils of the electro-magnet virtually to block the telegraph circuit against the telephonic currents, exactly as is done by the special retarding electro-magnets of the Van Rysselberghe system. Dr. Rosebrugh has more recently made several independent improvements of great value in the telephonic telegraph.

Finally, I come to the question of the influence of a Government, or of any other powerful controlling body, in affecting the development of telephonic invention. I would first of all say that the Western Union Telegraph Company were very wise in their generation when they made that arrangement with the American Bell Telephone Company that Mr. Rysselberghe mentioned. But I am not quite sure, bad as that arrangement appears to be for future independent telephonic enterprise, whether it is not something like this which our own Government intends to effect. Mr. Preece has told you, and I do not want to add anything to his words, of the effect upon telephonic invention of a large and powerful body controlling the telephonic interest; it comes to this, that in fact no one now dares to invent a telephone unless he has a company with ten or twenty thousand pounds of capital to back him up. But we know that for the purpose of public telephonic intercommunication the Government has obtained a decision that the telephone is a telegraph. Well, if the telephone is a telegraph, you have only to wait until all the principal controlling telephone patents expire, and then nobody except Government can work long-distance lines for intercommunication between towns. Professor Thompson.

Mr. T. H. BLAKESLEY: I hope I may be allowed in a few words to point out that some two years ago I called the attention of this Society to the very considerable effect which capacity—that is, the power to condense electricity—in any transmitting conductor produces in weakening an alternating current in its progress along that conductor. I most distinctly disagree with Professor Silvanus Thompson's views in assigning this effect wholly or chiefly to self-induction. Mr. Blakesley.

The effects are very distinct when the causes appear separately. Suppose, for instance, that in a wire whose capacity is negligible we have inserted at a point an electro-magnet—*i.e.*, considerable self-induction—then the current will be *equally diminished* for the same rate of alternations *all along the wire;* in other words, the position of the electro-magnet is immaterial. But if instead of an electro-magnet one terminal of a condenser is attached at the point, the other being connected either with

Mr. Blakesley. the return wire or the earth, as the case may be, then again the current is modified, but in the two sections differently. In that containing the source of electricity the current is increased, and in the further section it is diminished. Hence in any circuit possessing any capacity distributed along its course there must be a continual falling off of the current as more and more capacity is included in considering different points of the conductor. Such a decay of current will, in my opinion, be the chief obstacle to long-distance telephony, and the effect has not as yet received the attention it must eventually call forth. I gave this Society a rule by which this effect may be calculated for any given note when the electrical qualifications of the cable are known, these last being calculable by the ordinary rules. Since then I have formed tables based upon this rule, a portion of which I may here cite to bring into prominence this effect of capacity to which I call attention, and its calculation :—

$\left(\frac{2RK\pi}{T}\right)^{\frac{1}{2}}$	$\left(\frac{C_e}{C_o}\right)^2$	$\left(\frac{2RK\pi}{T}\right)^{\frac{1}{2}}$	$\left(\frac{C_e}{C_o}\right)^2$
0·0	1·	·8	1·0170708
·01	1·	·9	1·0273482
·02	1·	1·00	1·0416915
·03	1·	1·1	1·0610573
·04	1·0000001	1·2	1·0865066
·05	1·0000003	1·3	1·1192066
·06	1·0000005	1·4	1·1604328
·07	1·0000010	1·5	1·2115614
·08	1·0000017	1·6	1·2741325
·09	1·0000027	1·7	1·3497354
·10	1·0000042	1·8	1·4401355
·2	1·0000667	1·9	1·5472209
·3	1·0003375	2·0	1·6730244
·4	1·0010667	2·1	1·8197334
·5	1·0026043	2·2	1·9897036
·6	1·0054004	2·3	2·1854716
·7	1·0100056		

Here R is the resistance and K is the capacity of the line between the generating telephone and the distant end. T is

half the period of the note under consideration. Then, the Mr. Blakesley. conditions of the cable being known, the number in the first column may be calculated. The number in the second column will then represent the square of the relation of the current at the speaking end to that at the far end. To show clearly the effect produced, suppose *a favourable case.* An overhead wire possessing merely ·016 microfarads per kilomètre, and only 5 ohms resistance per kilomètre, is to be employed to transmit a note whose vibrations are 500 in one second; and suppose the line to be 90 kilomètres long. Then we have the means of calculating the number represented by $\left(\frac{2 \text{ R K } \pi}{\text{T}}\right)^{\frac{1}{2}}$. It will be found to be about 2. The number opposite 2 is 1·673, which represents the square of the current at starting to the square of the current on arrival. The root of this number is about 1·3, so that this current has been degraded by 3 parts in 13. This effect is the greater the higher the pitch of the note, so that we should feel no surprise when Mr. Preece, who has had considerable practical acquaintance with telephones, owns that low rumblings are often all that can be heard. M. Van Rysselberghe appears to have had a similar experience. The fact is that the low tones are the survivors, and the vanishing of sibilant sounds arises from their short periods as notes. In these effects, and not in failures of insulation, must we look for the limits of long-distance articulation. Want of insulation is no doubt a bad thing, but is a small obstacle compared with degradation of current due to capacity.

The smaller the resistance of the conductor the less baneful is the capacity, and on that account is it a good thing to substitute copper for iron, not so much because the self-induction is thereby diminished.

Touching self-induction, it is often considered an evil under all circumstances. This is by no means the case. Suppose we have a circuit closed by a non-leaking condenser, *i.e.*, one which on a bridge would show a resistance of value infinity. A telephone will, however, produce a current in such a circuit. If self-induction is then gradually added to the circuit by inserting iron wires into a

kesley. coil, the current will gradually *increase* until a certain point is reached, beyond which it will fall off. If at this critical point we take away both condenser and the causes of self-induction (the wires), and close the circuit over the breach made by the condenser, we shall find the *full effect maintained.* The presence of the self-induction with the condenser has been able to entirely annihilate the effect of the infinite resistance constituted by the dielectric of the condenser. [The critical condition is different for different periods, *i.e.*, pitches.]

A great deal more might be said upon this interesting subject, but I am aware your time is valuable, and will abstain at present.

Mason. Mr. GEO. A. MASON: I should like to correct Professor Silvanus Thompson on one or two things—First, that electric light carbon is not the carbon used in either Post Office instruments or the Blake instrument; it is carbon specially prepared and made entirely different. Secondly, the interest of the Western Union Telegraph Company and the American Bell Telephone Company is a joint interest, because the Western Union owns 45 per cent. of the Bell Telephone interest, therefore the interests must be identical.

The PRESIDENT: As the hour is very late, I must call on Mr. Preece to reply at once.

Preece. Mr. W. H. PREECE, in reply, said: I am sorry, Sir, that the discussion has been confined to so few speakers. I should like to have had to reply to a great many, and especially if the replies only required to be so simple as those I have now to make. A remark was made by an early speaker expressing regret that I had not called attention to the form and character of the instruments used by the Post Office. They are manufactured by the Consolidated Telephone Construction Company, whose manager, Mr. Mason, has just spoken to the meeting. Specimens are on the table for examination, and I think that the workmanship turned out by the Consolidated Telephone Construction Company of London quite equals anything seen either in America or on the Continent of Europe.

Now, Mr. Van Rysselberghe expressed a hope that when trunk wire working has developed on the Continent England will

not keep behind. I can promise him most faithfully that it will Mr. Preece. not; it never has kept behind when it has had its chance, and I hope that we shall some day show, by the working of the telephone system also, that at any rate England does not mean to be behind even the United States of America. If anybody wants to know one reason why England is now behind as regards telephony, I call the attention of everybody present to an account of how telephones are worked in this country in the columns of *Punch* to-day. It is a true description of the difficulties that nearly everybody encounters when desiring to speak through the telephone system in London.

I say, and I repeat the statement deliberately, that the question of speaking to a distance is not a question of powerful transmitters. There is no doubt that a powerful transmitter will speak better than a weak transmitter, but then I say that is not the question. The question of speaking to a distance rests with the wires and the environment of those wires; it does not rest with the transmitter. Mr. Van Rysselberghe has explained how he spoke through 1,100 miles with perfect ease without any special transmitter, any loud-speaking Hunnings, or the Turnbull improvements, or the Husbands improvement, or Professor Silvanus Thompson's improvement; but he spoke through the ordinary Hughes microphone; and his experience has shown that really the question is not one of transmitters, but of conductors, and of removing the disturbances that I have mentioned. It is a very common way of raising a discussion to impute wrong expressions to the man whose words are referred to. Professor Thompson quoted me as saying that the Post Office officials had made all improvements in telephones. I said nothing of the kind; I said "improvements in working in this country." All improvements in working have been introduced by the Post Office officials. We introduced double-wire working; we did not invent, but we introduced, the twisted wire. The twisted wire was invented by Professor Hughes, who has not suggested one improvement of any sort or kind that has not been readily tried, and, if suitable, adopted. There is no single man—I do not care who he is or from what country he comes—who presents an invention which is not tried,

Preece. and if it is an improvement, and proves capable of successful adoption, it is accepted and well paid for. If one wants to know how improvements have been adopted and are working, let him go to Newcastle-on-Tyne. There is no "calling" on the system there. A man goes to the telephones, lifts the tubes, and speaks to the exchange at once; there is no calling anyone—it seems like magic—no "Who's there?" When he has finished the conversation it is known at once by the replacement of his tubes; there is no mild, meek, indistinct female voice breaking in with "Have you finished?" The conversation is carried on as between two men together, and the moment it is over the exchange knows it, and a second subscriber is put through without loss of time. There is no overhearing, and no disturbance; everything goes on as perfectly between the six or seven towns I named in the North of England as it would in any local exchange.

I want also to correct Professor Silvanus Thompson on another very serious point, and it is one of the most curious errors, I think, that has ever become a public delusion. No decision of any court and no law has ever said that a telephone is a telegraph; it has never done anything of the kind. The Post Office has no more control over the telephone than anyone in this room. We cannot buy telephones, because the United Telephone Company will not sell us any. It was only by a clever piece of business, negotiated before a company was floated (since absorbed by the United Company), that we succeeded in getting the disposal of 20,000 telephones. What the court decided was that messages sent by telegraph, by telephone, by tube, or by any electrical means, between one person and another were telegrams, and came within the rights of the Postmaster-General. Nobody can send messages for money outside the Act of Parliament that controls the telegraphs of this country. The telephone is a telephone, and the Post Office has no control over the telephone whatever.

I am glad that Mr. Van Rysselberghe made his promise, and we will keep him to his word. He is about to carry two wires from Paris to Rotterdam and Amsterdam, and after he has carried out that project and proved the successful working of his system,

we will ask him to come over and give us a paper on the general subject.

A hearty vote of thanks was accorded to Mr. Preece for his communication, and also to Mr. Van Rysselberghe for his remarks and for his promise of further information.

A ballot for new members took place, at which the following candidates were elected:—

Foreign Member:

José Rodriguez Vera.

Member:

John William Ayres.

Associates:

R. Applegarth. | John James Tough.

Student:

Ernest Lacey.

The meeting adjourned.

The One Hundred and Fifty-seventh Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, May 27th, 1886—Professor D. E. HUGHES, F.R.S., President, in the Chair.

The minutes of the last meeting were read and approved.

The names of new candidates were announced, and this being the last meeting before the recess it was agreed, upon the motion of the President, that, following previous custom, the candidates should be balloted for that evening.

Foreign Members:

Dr. William W. Jacques. | F. A. Lanza.
H. Serrin.

Member:

Sir James N. Douglass.

Associates:

Hans E. B. Atkinson.	James Douglas Dallas.
James Brayshaw.	Léon Drugman.
William Arthur Coulson.	Samuel Spence Parkyn.

George Henry Robertson.

Students:

Charles Alfred Baker.	Charles S. D. Fisher.
Harold Read Braid.	Louis Campbell Login.
Frederick W. M. Chapman.	Bertram Thomas.
William Foreman Collins.	Ernest George Tidd.

Francis Lovell Todd.

Donations to the Library of the Society were announced as having been received since the last meeting from the Franklin Institute, Harold Imray (Associate), and R. von Fischer-Treuenfeld (Member), to whom the thanks of the meeting were duly accorded.

The SECRETARY announced that an interesting donation had been made to the Society, through Mr. W. H. Preece, by Mr. Leonard Wray, of Perak, in the Straits Settlement, accompanied by a letter, from which the following extract was read:—

[*Extract of letter from Mr. Leonard Wray to Mr. Preece.*]

"Perak Museum,
"Perak, Straits Settlements,
"*March* 23*rd*, 1886.

"I am sending you, by favour of Mr. W. T. Thiselton Dyer, of Kew, a box containing botanical specimens of gutta-percha and india-rubber producing trees, collected in Perak by myself, and shall be much obliged to you if you will kindly present them for me to the Society of Telegraph-Engineers.

"They are duplicates of a series I have sent to Kew, and which are being examined by Mr. Thiselton Dyer, who informs me that he is preparing a paper on them to be read before the Linnean Society.

"Thinking that there is no body of men to whom the life history of these plants is of such interest as to telegraph engineers, I obtained the permission of H.M. Government of Perak to present the collection to their Society; and trust that they will be able to find space for it among their collections.

"I would suggest that the specimens be poisoned, mounted, and framed, otherwise they are sure to get destroyed. They have cost a large sum of money to collect, and are therefore worth taking care of.

"I am, yours truly,
"L. Wray, Jun.

"W. H. Preece, Esq., F.R.S.,
"General Post Office, London.

A hearty vote of thanks was unanimously accorded Mr. Wray for his valuable donation.

The following paper was then read :—

THE TELEPHONE AS A RECEIVING INSTRUMENT IN MILITARY TELEGRAPHY.

By Captain P. Cardew, R.E., Member.

I have been asked to give you a short account of the system of telegraphy with vibration currents, using the telephone as a receiving instrument, which was invented by me five years ago, and has since been used with considerable success in several campaigns.

Major-General Webber, C.B., R.E., alluded to this system in his interesting paper on "The Telegraphs of the Nile Expedition" read last session, but as any detailed description would have been foreign to the scope of his paper he could only mention it in a few words, which may perhaps convey an erroneous impression to

this extent—he spoke of the vibrator arranged by me as constructed on the same principle as that of Elisha Gray.

Now, what I introduced into the service was a system of telegraphy which indeed included a vibrator modified from existing instruments, but neither the system nor the vibrator were on the same principle as those of Elisha Gray, in whose system, as is well known, transmitters and receivers, each limited to one note, are used, the object being the simultaneous transmission of a number of independent signals on one wire, whereas in my system the object is the utilisation, to the best effect, of the telephone, which will, of course, respond to any note, as a receiving instrument.

The system I am about to describe has been kept secret by us hitherto, but as something very like it has been applied to communication with moving trains, and as it is certainly well understood by the principal makers of apparatus, I have without difficulty obtained permission to describe it and the experiments made with it.

This will, perhaps, be best done by detailing the steps by which it was reached.

Shortly after we became possessed, at Chatham, of any really well-made telephones, the idea of using them as receiving instruments, for telegraph messages sent by the ordinary Morse code, struck Major Armstrong, who was then in charge of the Electrical School, as probably applicable to field telegraphy, where interference from induction from parallel wires was not to be apprehended, and where the extreme sensitiveness of the instrument would probably enable work to be carried on in spite of faults of insulation, hasty joints, bad earth connections, &c.

This idea was worked at for some time. It was found that there was some difficulty in reading, due to the almost perfect similarity of the make-and-break clicks in the telephone and the consequent liability to read the signals reversed. Still, this was probably to be overcome by practice, and eventually it was determined to try through what length of bare wire laid on the ground without any insulation the method would admit of carrying on work.

Some experiments had also been carried out at this time with some vibrating sounders sent for trial by Messrs. Theiler.

These consisted of simple electro-magnets, the armatures being attached to a piece of German-silver spring, fixed at both ends, and with a contact screw arranged so that when the armature was attracted it broke the current through the coils; in fact, just on the same principle as an ordinary chattering bell, but arranged to give a musical note.

They were intended to be used as ordinary sounders, but the difficulty was that they interfered with each other if more than two were used on one circuit.

The following is an extract from a report I made to the Royal Engineer Committee on the experiments carried out with this bare wire:—

"REPORT on an Equipment with 15 miles of bare wire laid on the ground, with a view to ascertain the possibility of signalling through it by means of telephones.

"Telegraph School,
"School of Military Engineering, April, 1881.

"The wire consisted of 10 miles of No. 16 B.W.G. soft iron galvanised wire, and 5 miles of No. 16 B.W.G. copper wire. This arrangement possessed the disadvantage of keeping a continuous current on the line from the earth contact of the two wires, and of tending to destroy the iron wire, but, as the line was only required for a short time, this was not material.

"Permission was obtained from the authorities of the London, Chatham, and Dover Railway, to lay the wire at the side of their line of rails. It was consequently laid in a loop extending from a short distance on the up side of the New Brompton Station to within a short distance of Newington Station, and back again on the other side of the line.

"To ensure the wire being well out of the way of the traffic, it was laid in the *hedges* in many places. In other places it was laid on the ground, even picketed down under stiles so as to prevent its tripping people up. The ground was generally newly made or garden ground, and the soil of fair conductivity. Rather more than half the wire was thus laid in the hedges.

"At road crossings the wire was stretched over a pole at each side.

"For convenience, one end of the wire was brought into the R.E. Institute.

"This necessitated using poles to avoid interference with traffic, and for convenience some poles carrying existing lines were made use of. This introduced induction signals, so that, in getting signals through, the following difficulties had to be contended with, viz.:—

"1. Very bad insulation.

"2. Continuous current from the different metals in the line wires and earths employed.

"3. Induction currents confusing signals.

"The line resistance was never accurately obtained, this being impossible under the conditions, but it must have been about 900 ohms, while the insulation test from the Institute gave on several days a resistance as low as 300 ohms, which of course included part of the line resistance, the position of the resultant fault being at any rate some distance beyond the end of the insulated wire, so that the true insulation resistance must have been extremely low.

"The first intention was to use the telephones as Morse instruments, with an ordinary key as before proposed, the connection being as shown in Fig. 1.

"This was tried with batteries of 10 Leclanché cells at each end. At the Institute, in a quiet room, there was no difficulty in reading these signals, but the ear had to be kept quite close to the instrument. At the other end there was some difficulty in reading signals when first tried, owing to a very high wind producing noises in the telephone. To get over this I tried the effect of putting on a Theiler sounder, as in Fig. 2, thus sending a vibratory current out to line.

"This was completely successful, the note produced being very easily read and quite distinct from the induction signals, and the noises due to earth currents.

"Signalling was carried on for several days by this method, without any difficulty, clearly demonstrating that by this means

signalling can be kept up through bare wire laid on the ground (as rapidly as cable), and afterwards poled and insulated when circumstances permit.

"Another advantage of this use of the telephone is, that no adjustment of the receiving instrument is ever necessary, thus eliminating a fruitful source of delay.

"For ordinary insulated lines the battery-power required is very small, and the telephones are ready when necessary to be used in the ordinary way, and would no doubt be found very useful by the General and his staff as a means of personally communicating orders.

"Another method of connecting the Theiler sounder is shown on Fig. 3. This I think preferable to Fig. 2 in general, for the following reasons:—

"1. The current through the Theiler sounder is practically uninfluenced by any change occurring in the line resistance.

"2. In the case of a dirty back contact in the key (a fault of frequent occurrence causing much delay), continuity will still be established through the coils of the Theiler sounder.

"3. Fewer cells can be employed (four cells Leclanché being quite sufficient for ordinary circuits).

"The note given by the Theiler sounder in the telephone is quite as loud as the tone of the ordinary sounder under ordinary circumstances. When working through bare wire laid on the ground it is of course low, but still quite distinct if held close to the ear.

"A simple apparatus for holding the telephone in the required position, so as to leave the arms free, could be easily designed. Two telephones, one to each ear, might then be advantageously employed.

"From the results of this experiment with bare wire, I feel confident in recommending the employment of this combination of Theiler sounder and telephone in place of the ordinary sounder for field service, over which it possesses the following advantages:—

"1. The possibility, as demonstrated, of working through a considerable length of bare wire.

"2. The receiving instrument requiring no adjustment for altered conditions of line and different stations, &c.

"3. The reduction of the battery-power required to be carried to at most one-fourth of the present requirements.

"4. The continuity of the line being ensured, independently of the back contact of the key.

"5. The power of working through very bad earths, saving much time in very dry places.

"6. That the note signals are more easily read than the interval signals by men untrained to either."

Experiments were immediately afterwards carried out by the field-telegraph troop at Aldershot with this system, which was reported on very favourably by Colonel (then Major) Hamilton, R.E., commanding the troop, from whose report I need only extract the following paragraph:—

"I should add to the above, that the experiment was tried of poling the line which had been laid on the ground while messages were being sent through the line, and the poling did not in the least interfere with the reading of the messages. It therefore follows that a line of bare wire may be laid as fast as an army advances, and that a party may follow slowly and pole the line; the communication being established from the first laying out of the line."

An extensive trial of the system was in consequence approved. Rather unfortunately, in order to save expense, it was proposed to convert the existing old pattern field sounders into Theiler or vibrating sounders. These instruments were mostly in a shaky condition, and in consequence were liable to get out of adjustment when used as vibrators, for which purpose it is essential that all parts of the instrument, except the vibrating tongue, should be very firmly fixed.

Some of these converted instruments and telephones were taken out to the first Egyptian Expedition, in 1882; and this system was used exclusively in sending the messages from the field of Tel-el-Kebir from 8.30 a.m. to 6 p.m.—115 messages, averaging 30 words each, being recorded as having been sent during this time, while some messages were unrecorded.

A new pattern of vibrator was, however, then considered essential, and this was the pattern designed. [*See Fig. D.*] As the noise made by the vibrator and the telephone at the sending end was sometimes a nuisance, it was reduced to a minimum in this instrument by using a very light armature—simply a piece of ferrotype or tinned iron—and by means of this small key at the side of the signalling key which, when depressed by one finger, short-circuited the telephone.

It was considered desirable to practically determine, if possible, the limit of distance to which the system was workable on a long aerial line isolated from other wires. As this could not be obtained in England the Indian Government was asked to try the experiment, and the following is an extract from the report of the Electrician of the Government Telegraph Department:—

"Weather clear and fine.

"Worked Tuticorin, a distance of 375 miles, by wire from Calicut, with 30 Minotto cells, reducing battery subsequently to four cells. Signals from Tuticorin very clear, and could, with the stronger current, be read on telephone held at some distance from the ear; but with the weaker current it was necessary to hold the telephone pressed against the ear.

"The thick, or No. 1, armature, was used at both ends throughout.

"The two parallel wires to Beypore (9 miles) and Malapuram (18 miles), also line to Vayitri and Tellicherry, were working at the same time, and all together during the above experiments, the two latter being suspended on same posts as the others, for a distance of ten yards from the office only.

"The beats from the offices working as usual were distinctly audible in the telephone, but, except when the weaker battery of four cells was on, the signals from Tuticorin on the vibrator were not interfered with—the musical note riding above the induction beats. Following day, weather cloudy and some rain.

"Worked Tuticorin at 7 hours, beginning with 10 cells and decreasing to 2 cells. The lines were disconnected at Cochin, 125 miles from Calicut, and the ends of the wires thrown down and, lying on wetted floor of signal-room, worked well with 4 cells."

This clearly shows that, with an isolated aerial line, very great distances could be worked by this system without translation.

In 1883, some experiments on General Post Office wires were made with this system, of which the following is a condensed report:—

"1*st Experiment.*—New Cross to Chatham (30 miles), worked easily with one cell, and very good signals with 6 cells; also worked through wet string and human bodies.

"2*nd Experiment.*—New Cross to Bristol, 123 miles on poles and 8 underground. Chatham to Bristol, 158 on poles and 10 underground—wires on the same poles—could hardly get through with 60 cells.

"Ordinary apparatus worked with 30 cells.

"The vibration currents were destroyed by induction, especially in the underground part through London.

"3*rd Experiment.*—Two parallel wires between New Cross and Dover, with vibrators. New Cross could read messages sent on both circuits simultaneously. Dover was not so successful, chiefly because the operators were not accustomed to read by sound. Signals audible with 2 cells and good with 5—67 miles open and 2 miles covered.

"4*th Experiment.*—Two parallel wires between New Cross and Chatham, fitted with ordinary ink-writers, also between the two vibrators and condensers, as in diagram."

This was an idea of mine to get an independent vibration-circuit superposed on ordinary working, and was quite successful—all three circuits working quite independently. Signals audible with 2 and good with 10 cells on vibrators—30 on the Morse.

In place of the condensers an ordinary plate lightning protector was fitted, and afterwards a resistance of 10,000 ohms, without interrupting the working.

"5*th Experiment.*—New Cross to Chatham. To each end of one of the wires, between New Cross and Chatham, both vibrators and Morse recorders were connected, the vibrators being separated from the line wire by the plates of condensers.

"When Chatham sent simultaneously on both his instruments (separate messages, of course), New Cross could read on both his;

but when Chatham sent on his vibrator at the same time as New Cross sent on his Morse instrument, the signals could not be read, but became mixed up and confused.

"6th *Experiment.*—Two wires known as 197 and 198 were tapped at Bristol station and Paddington (118 miles apart); these wires were not cut or terminated, they were carrying powerful currents from the General Post Office to stations in the West of England and South Wales.

"Between them, as in Experiment 4, were placed vibrators and telephones.

"The experiment was a failure, as, owing to the strength of the working currents, the signals in the telephones were completely overwhelmed by the noise of the induced currents. Occasionally, at intervals, the signals sent from Paddington were audible for a moment.

"7th *Experiment.*—One wire, 193, running parallel to the above was cut at Bristol and Paddington, and vibrators and telephones fixed upon it. Communication was carried on, in spite of the induction from the neighbouring wires.

"8th *Experiment.*—A cable containing seven wires runs between Dublin and Holyhead, about 65 miles. Six of these carry the ordinary postal telegraph business, the seventh is 'dead,' *i.e.*, has become so earthy that none of the ordinary telegraph instruments will work it. Vibrators and telephones were accordingly placed in connection with this dead wire; owing to the induced current from the other wires communication could not be carried on until the working upon them had been temporarily suspended. As soon as these currents ceased, however, messages were successfully exchanged over 'the dead' wire by the vibrators.

"9th *Experiment.*—A bare G.I. wire was laid alongside of the railway on the ground, from Chatham to Faversham, about 16 miles—it was in contact with the railway signal wires and with stay wires, and piles of sleepers and of railway iron, which had been deposited upon it—vibrators were, as before, joined to it: at first no satisfactory results were obtained; the wire was

cleared from contact with the signal wire and some of the stays, and afterwards communication was successfully established, interrupted sometimes by the noise of passing trains." *

In commenting on these experiments on 1st October, 1883, I remarked: "It is worth consideration, whether the system of working tried successfully in Experiment 4 could not be usefully adopted in the postal telegraphs. . . . . . . The method is much improved by the addition of magnets on the Morse circuit, as the Morse clicks can be practically softened off in the telephone to such an extent, by being passed through the coils of a magnet, as to avoid all interference with the vibration signals."

Immediately after this I tried the effect of working as in Experiment 5, but with the addition of an electro-magnetic coil of considerable inductive power, on each end of the line, between the Morse instruments and the vibrators, and found it work perfectly.

This method was soon afterwards tried between New Cross and Chatham, and worked perfectly, although the condition of the line was so bad and variable that we could not succeed in duplexing the Morse. By this method, therefore, two independent circuits can be at once established on a single wire with single instruments, without any balancing or nice adjustments.

In order to simplify the connections for field purposes, I obtained some $\frac{1}{3}$ M.F. condensers and magnet coils and fixed them inside a small box with three terminals outside, marked M, L, and V—the coil being attached to M and L, and the condenser to L and V.

The boxes were then filled up solid with white paraffin, and the ends secured. They were, I think, about 9 inches by 4 by 3, or perhaps less. The iron cores of the magnets were joined at both ends to form a complete magnetic circuit. To these boxes I gave the name of "separators." [*See Fig. B.*]

The instructions were simple:—"Join the Morse to M, the line to L, and the vibrator to V, and fire away."

* Attempts were made to work along the bare wire with the ordinary Post Office relay. Signals could not be obtained further than about a mile.

They were made in a great hurry for the last Bechuanaland and Suakim expeditions—in fact, the paraffin was still warm when I put them into the hands of Colonel Turner, R.E., on board the "Queen."

Unfortunately, pressure of work, and a laudable disinclination to try new-fangled apparatus on service, caused them to be laid aside; but I have no doubt whatever of their working. Of course it is evident that this separator system is practically the same as Van Rysselberghe's, but it was brought out quite independently, and in the manner detailed; and the fact that he can successfully employ it with the weak speaking currents shows how certainly it must work with the far more powerful vibration currents.

Quite recently an account has appeared in the papers of a somewhat similar system brought out by Mr. Edison, and marked with his usual ingenuity. No doubt it will be taken up now that the prophet belongs to another country.

Although the separators were not tried either in Bechuanaland or Egypt, the vibration system was found very useful, notably in one case in Egypt, where working was carried on for six weeks through a bare wire laid on the ground for a distance of 23½ miles, from Kaibar to Abu Fatmeh, and absolutely buried for a distance of 200 yards through the camp at Kaibar. This distance is rather longer than that worked through in England, viz., from Chatham to Faversham; but it was not really so severe a case, as the ground in the Soudan was decidedly dry, and that in England distinctly wet. The most noteworthy feature of this trial is that only two small Leclanché cells were used at either end, and that with this small battery-power, through a line making dead earth all the way, the call signal was audible, even without holding the telephone to the ear.

The vibration system is now applied by us in many ways. For instance, with ordinary telephones a buzzing armature is fixed to the induction coil, causing a vibratory current in the primary circuit, which is reproduced as a call signal in the telephone, thus dispensing with the ordinary bell. The note is loud enough to be heard in an adjoining room. [*See Fig. C.*]

I have also adapted it to an instrument for testing lightning conductors. [*See Fig. A.*]

The instrument was got out before the publication of our President's most valuable researches in the field of self-induction, and I did not see my way to obtaining anything better than a minimum of note when arranged for balancing very low resistances. A sonometer has since been added to it, the effect of which I have not yet tried, but which I expect will overcome the difficulty.

We are not yet quite satisfied with our pattern of vibrating transmitter, and Messrs. Theiler, who unconsciously produced the first one, have recently brought out an improved pattern, which, with some modifications, will probably be adopted.

It is worked on a primary low resistance coil, and the secondary coil throws an alternating induced current on line.

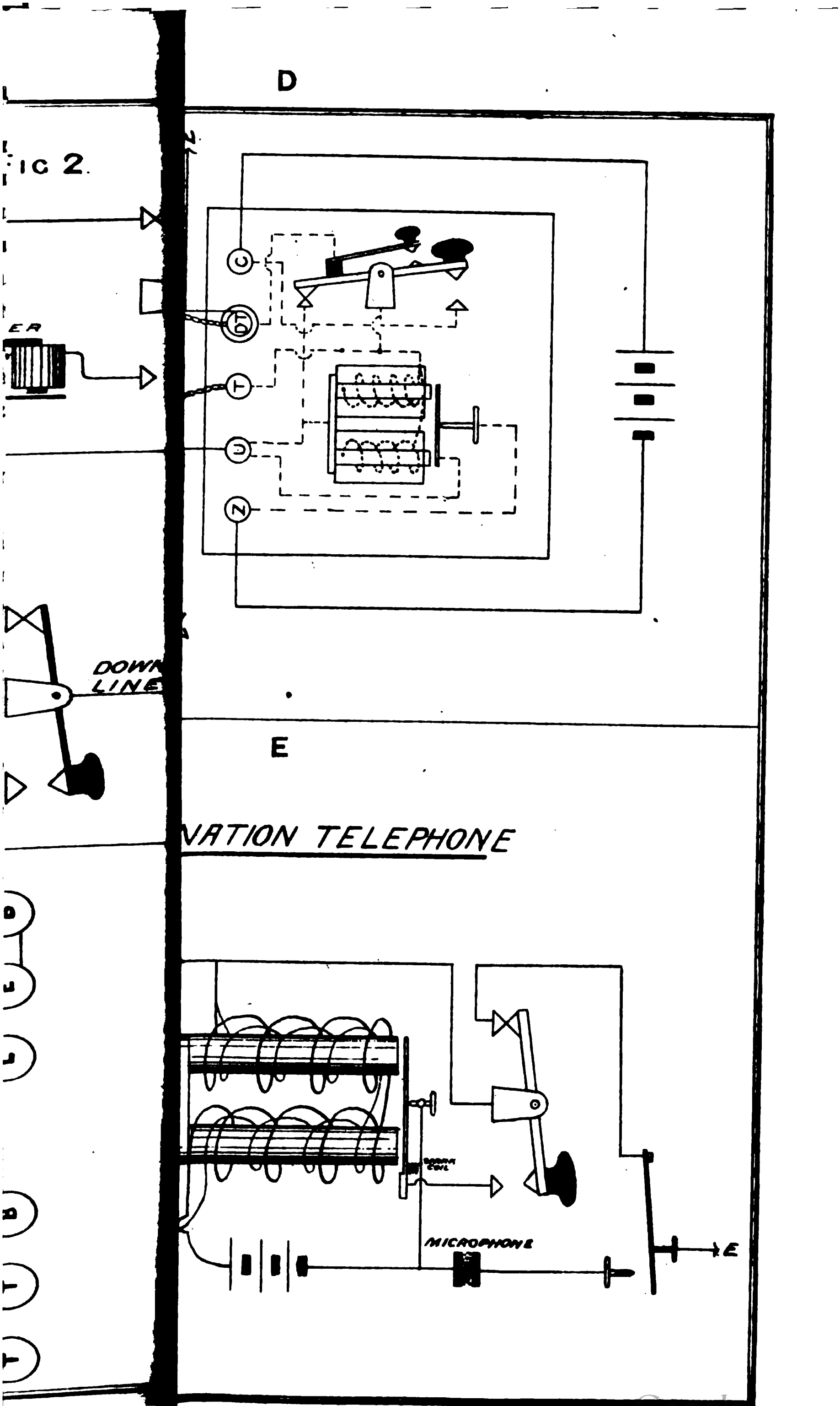
I had never taken to this obvious modification, except as a call signal for telephones, as the simpler form enabled increased battery-power to be more effectually used, but the power of the purely induced current in the telephone is certainly marvellous, and this pattern, with three cells, has given as loud a note as our present pattern with ten cells, under all conditions of artificial line.

The last instrument I submit to-night is a "combination box," adapted for speaking or telegraphing. The connections are as shown in Fig. E.

The vibrating transmitter is double wound, and acts as an induction coil for the transmission of speech. The microphone transmitter used is a "Hunnings" or "Moseley," arranged with a handle which forms a switch. This solution of the switch difficulty, which gave us some trouble, is due to Quartermaster Sergeant Kenney, R.E., and is certainly the most efficient we have yet tried. It performs two offices: when speaking, it is squeezed in the hand and completes the circuit through the microphone and primary coil; when listening, the pressure is relaxed, the battery circuit is broken, and the secondary coil short-circuited. Thus the battery circuit is never kept on longer than is absolutely necessary—a most important point in the field, where small patterns of cells must be used and renewals may not be at hand.

...e
...esident.

The PRESIDENT: We have to-night listened to a very interest-


D
IC 2.
ER
C
DT
T
U
Z
DOWN
LINE
E
NATION TELEPHONE
MICROPHONE
E

ing paper upon a subject of great importance. We may all be quite sure that the system described is a perfect success—it *must* work. I am surprised that it only worked the distance it did, and should have thought it would work very much further; certainly, the telephone will work to a far greater distance and through far greater difficulties with a vibrating sounder than it will with speech—we are very well aware of that. I now invite discussion.

Major C. F. C. BERESFORD, R.E.: Mr. President and gentlemen,—I think that Captain Cardew has been working entirely in the right direction in bringing forward a simple and portable instrument of this kind for advanced telegraphy in the field. Advanced telegraphs are quite a different thing from the telegraphs which we employed in our late expeditions, which were simply for keeping up the army communications. Outpost telegraphy, or advanced telegraphy, is a perfectly untrodden field in the British army, and in most other armies in Europe, and I have not the slightest doubt that in the next European war the intelligent use of outpost telegraphy will give to the army employing it a trump card of no mean importance. Major Beresford.

As regards Captain Cardew's separator, perhaps I am somewhat to blame for not having used it at Suakim. When I went out first, we were all very busy with one thing or another; I saw among our stores then a box, and, asking what were its contents, was told that it was a combination instrument. We were very much occupied at the time trying to keep our lines free from the Arabs, and having to repair them as fast as they were broken down, and I did not think it advisable, amid the press of work, to experiment with this combination instrument. There is no doubt that a separator, of the kind shown us to-night, will be most valuable, because we are at present bound down to single wires on our poles, or, at the most, to two wires. The difficulties of transport prohibit the use of stronger poles, and anything which increases the carrying power of the wire is much to be desired.

One point about using a vibrator, which ought to be remembered, is its effect upon the operators, considering the heavy traffic

or
esford.

we have to work on our telegraph lines in the field. Some of the clerks who worked the system at Suakim and on the Nile state that they could not stand the buzzing in their ears for any length of time; the vibration may produce ill effects upon the brain, and though I am not quite certain how far the failing has proved to be general, yet I have some idea that continual buzzing in the ear might perhaps, sooner or later, produce a "bee in the bonnet."

. Von
cher
uenfeld.

Mr. R. VON FISCHER TREUENFELD: Mr. President and gentlemen,—Everybody interested in military telegraphy will be certainly very much obliged to Captain Cardew for having brought before the Society such an interesting subject and such a useful apparatus, especially as it comes from an officer to whom military telegraphy is so very deeply indebted. But I trust Captain Cardew will pardon me if I raise a point, not with the intention of throwing any doubt upon the efficiency of his system, but with regard to the admissibility of a field telegraph instrument of a non-recording type. I know that in this respect opinions in military telegraph circles are very different; for instance, in the German army (the system in which, I think you will agree with me, is based upon great experience and upon principles which have been thoroughly worked out), you will find that much objection exists to the employment of any apparatus that leaves no record of its signals. I believe I am not going too far if I say that I have commented upon and published about Captain Cardew's instrument perhaps more than the inventor himself, but I must say that I have met with some very serious objections on the part of strategical officers of high command, and especially in the German army. Recently, for instance, Major-General Von Chauvin wrote a book on field telegraphy, in which he most decidedly objects to any instrument of such a kind, be it a vibrating sounder, be it a telephone, or any other instrument which does not record its messages. A more recent writer in the German army—Baron Von Massenbach—not only objects very seriously to the employment of any such instrument, but actually ridicules the idea, and says that it would not be in accordance with the practice of any well-organised military reporting service. In the German army it is only the vedette, or what in England is called the double sentinel, who reports verbally; the corporal or

sergeant takes his reports to the picket, but has to sign his name and be responsible for the report which has come from the front, and in higher quarters than that, recorded reports only are admissible. The same subject arose here some years ago, on the occasion of the discussion on Lieutenant Jekyll's paper on "Military Telegraphs and the Ashantee War,"* and I myself at that time, acting upon my own military experience with sounders, spoke against the non-recording instrument; but I do not hesitate to say that I have changed my opinion, and I personally am in favour of the vibrating instruments, because they admit of the possibility of telegraphing on badly insulated wires, and hence make it possible to push forward the telegraphic service more to the front than has been hitherto practicable. But seeing the difference of opinion as to whether such acoustical messages are admissible in an army, I should be much obliged if Captain Cardew, or any of the officers who have had experience, would favour us with their views on this point, because the result may perhaps lead to the withdrawal of the objections which have hitherto been raised in very high quarters against such instruments. Mr. Von Fischer Treuenf

The PRESIDENT: We have present this evening Dr. Jacques, Electrician to the Bell Telephone Company of America, and we should be glad to hear any remarks he may favour us with.

Dr. JACQUES: Mr. President,—I came in this evening merely to listen to what might be said on the subject, but as you have called upon me I will just say one word in connection with this paper, in which I have been very much interested. I had occasion some five years ago, when we were first extending our lines, to notice a good deal of disturbance from one telephone to another, and particularly from a telegraph line to a telephone line. Following up the subject, I made practical use of the effect, and, although we did not advance so far as has been related this evening, we found that we could overhear the signals from telegraph lines which were in some cases several miles away from our own short line. So we constructed a line about half a mile in length, and in order to get a strong signal we used an interruptor, on something of the plan described this evening; Dr. Jacq

* Journal of the Society, part 9, vol. iii., p. 459.

'acques. then, at a distance of some six miles from that half-mile line, we constructed a second line, which was something less than half a mile in length, and into that we put merely a Bell telephone. Now, the interruptor was continuously working, and, by the use of a Morse key, signals were transmitted through it, and when these signals were interpreted into the Morse alphabet they gave on the telephone, six miles away, perfectly audible signals, and we were able to telegraph in that way, backward and forward, by duplicating the apparatus, so as to have a transmitter and a receiver at each end.

The experiments were not carried further than that, and I did not know that they would ever be of any practical value; but I speak of them now, particularly in connection with what I noticed in Captain Cardew's paper of the persistence of such signals over lines which were interrupted. It would seem, from the experiments of Captain Cardew and those which I have referred to, that such a method of working would be particularly of value on lines liable to interruption; for here is a case in which the line at each end was only half a mile long, and it was interrupted for a distance of six miles, the only conditions differing from an ordinary telegraph line being that where it was interrupted it was carried to earth. It shows at least a very great superiority of telegraphing by this method over the ordinary methods.

ovan. Mr. H. C. Donovan: Mr. President and gentlemen,—I would just make a remark upon what Mr. Treuenfeld said in regard to the objection that German military men have to an instrument that does not record, and say that I believe during the whole of the American War the Morse sounder was used entirely, and with, I think, the approval of the generals in command of both armies.

'reece. Mr. W. H. Preece: Sir, I can endorse nearly all that Captain Cardew has said to-night on that part of the subject that interests me perhaps more than the application of the system to military telegraphy, and that is the means that it supplies us with to increase the capacity of wires for the transmission of messages; for it stands to reason that that is a subject that must always and ever occupy my closest and constant attention. It was the prospect of some such advantage being received that

induced us in the Post Office to give Captain Cardew every possible Mr. Preece facility to carry out his experiments. Now, there are many difficulties and many reasons why this system is not practicable or applicable on a large scale. I will not give you them all, but I will first give you the one principal reason, and that is, that already on our Post Office wires we use what may be called a vibrating system. The Wheatstone automatic apparatus, which has been of recent years improved so much, now works at the rate of 400 words a minute, and that speed means 200 reversals per second. The vibration of an ordinary man's voice is about the same, hence on wires worked by the Wheatstone apparatus, or on lines affected by the Wheatstone apparatus, it is found quite impossible to super-impose the rhythmical vibrations required by the telephone upon the irregular vibrations required by the Wheatstone—in fact, on what we may call the noise of automatic circuits, for the only difference between noise and music is simply rhythm.

Then there is the difficulty that Captain Cardew referred to, and that is the difficulty arising from underground wires. Well, that is a small difficulty. Another reason is this, that you will see in the fourth experiment that it has been possible to make out of two circuits a third, and that is a very simple and a very practical process indeed, but the misfortune is that whenever two wires exist out of which a third can be obtained, practically, by means of this system, it is invariably found to be in a place where a third wire is not wanted. We have gone really very far ahead of anything that has been foreshadowed in this paper. As you know, or as I hope you know, for I always bring everything I possibly can before the Society, during the year 1884 I visited America, and there found a system at work called the "Delany System;" it was exhibited at the Inventions Exhibition last year; we have tried it on our Post Office system in fact, and, instead of converting two circuits, like those [*pointing to diagram*] between New Cross and Chatham, into three, it will convert those two circuits into twelve, and I think you will acknowledge that twelve circuits are better than three. This system will, I hope, be described in our next Journal.

Preece. Attention was called by Captain Cardew to a mode of attracting attention by using the vibrator. Well, we have had this principle in practice in the Post Office some time for a very useful purpose. Most people who use the telephone know that there is a strong habit of leaving the telephone off its switch, and, in the Gower-Bell telephone that we use so much, the tubes are often left hanging down (out of the arms) by subscribers. Well, when the receiver is off its switch, or when the tubes are left hanging, there is no means of attracting the attention of a subscriber—you may press the button, but his bell will not ring—so we supply what we call a "howler," and whenever a subscriber leaves his tubes hanging this howler is at once put on; and we have not yet found a subscriber who would stand its sound for more than two minutes.

The President: The hour is rather late, and I must call upon Captain Cardew to reply.

Capt. Cardew. Capt. P. Cardew, R.E., in reply, said: As regards Mr. Von Treuenfeld's objection to the use of acoustic telegraphs, that has been partially answered by the remarks of Mr. Donovan as to the practice that obtained in the American War, and it has also certainly been found in our last expeditions (which are not certainly wars on a scale equal to those in which Germany has been engaged) that the recording instrument was not required; and I think Major Beresford will agree with me that the vibrating system, or the ordinary relay and sounder system, have formed the staple method of working, recorders not being used at all. So many miies and miles of recording slip would be used that it would take the lifetime of any General or Staff-officer to attempt to go through and check them.

It was a very interesting experiment that Dr. Jacques brought forward. A somewhat similar experiment has been tried with the vibrators in England across the Solent. Parallel wires run on either side, one on the Isle of Wight side, the other on the mainland, and working across the Solent was carried on through the water.

As regards Mr. Preece's observations, I would not attempt to work this system against the Wheatstone automatic (I know the result is something awful), but, of course, we do not use the

Wheatstone automatic in the field; nor are we likely, I think, from what I have seen and heard of it, to work the Delany multiplex telegraph, which is very pretty as far as it goes, but is not, I think, quite so simple and substantial as the vibrating system, which does not get out of order, and is worked in the simple manner I have described. Capt. Cardew.

As to Experiment No. 4, it does convert two wires into three, and the separators convert one wire into two. Our modest aspirations have been satisfied with that so far.

The PRESIDENT: We have had an interesting discussion upon Captain Cardew's most valuable paper. The question of recording telegraph-instruments and sounders for military purposes is one which each military organisation can best decide for themselves, but between the ordinary Morse sounder and the telephone sounder the advantage seems to me greatly in favour of the telephone, as it requires no adjustment, and is able to work through obstructions and loss of insulation that would be fatal to the ordinary Morse. I therefore agree with Captain Cardew in regarding the system which he has presented to us as one eminently suitable for military purposes. The President.

I am sure that you will all, equally with myself, have highly appreciated Captain Cardew's paper, and will accord him a most hearty vote of thanks.

A vote of thanks to Captain Cardew was unanimously passed.

The following paper was then read:—

ON A PROBLEM RELATING TO THE ECONOMICAL ELECTROLYTIC DEPOSITION OF COPPER.

By Captain H. R. SANKEY, R.E., Member.

At the beginning of last winter I was asked by Mr. W. Goolden (of the firm of Goolden & Trotter) to assist him in a scheme for depositing copper on a large scale, and in discussing the question the following problem presented itself:—

Let it be assumed that an installation for the electrolytic deposition of copper consists of a number of depositing tanks, each containing the same cathode area and supplied with current

by one dynamo, whose activity is given. Find what number of tanks, what cathode area per tank, and what density of current per square foot of cathode should be adopted, and in what manner the tanks should be electrically connected in order that the copper may be deposited at a minimum cost.

This problem, although of considerable practical importance, does not appear to have been attempted, at anyrate in a theoretical manner. It is a somewhat complicated problem, and the following does not pretend to be more than a preliminary and approximate solution, though probably sufficiently accurate for practical purposes.

In the first instance the tanks will be supposed to be arranged in simple series.

Let

n = number of tanks;

S = surface of cathode per tank, expressed in square feet;

γ = density of current per square foot of cathode;

r = tank-resistance per square foot of cathode;

ϵ = counter electro-motive force of each tank;

then

γ S = current flowing through each tank;

$\frac{r}{S}$ = resistance of each tank (not including leads);

and therefore the energy absorbed by *one* tank is

$$\frac{r}{S}\gamma^2 S^2 + \epsilon\gamma S,$$

and the energy absorbed by all the tanks is

$$n\left(\frac{r}{S}\gamma^2 S^2 + \epsilon\gamma S\right).$$

The energy absorbed by the leads only remains now to be accounted for. Whatever the number and size of the tanks, this portion of the energy can, by arranging the leads, be made equal to any desired proportion of the total energy expended in the circuit. A suitable assumption would therefore appear to be to make the loss of energy in the leads constant, in which case it can be expressed by a CV, a being a constant to be afterwards determined.

Hence, from the conditions of the problem,

$$n\,(r\,\gamma^2\,\mathrm{S} + \epsilon\,\gamma\,\mathrm{S}) = (1 - a)\,\mathrm{CV} \quad \ldots \quad (1)$$

which is the equation of energy.

Now, the cost of depositing *one* lb. of copper is

$$= \frac{\text{daily cost of all the tanks + daily cost of activity + daily cost of superintendence, \&c.}}{\text{weight of copper deposited per diem,}}$$

and it is required to find what values of n, γ, and S make this expression a minimum.

The first step is to find expressions for the various items of expenditure, and for the weight of copper deposited.

Daily Cost of all the Tanks.—This item will clearly be n times the daily cost of *one* tank, which it is found can be expressed by

$$k + k_1\,\mathrm{S} + k_2\,\mathrm{S}^2 + k_3\,\mathrm{S}^3,$$

where k, k_1, k_2, and k_3 are constants as regards any particular installation. This expression will be denoted by $\phi\,(\mathrm{S})$.

The factors k, k_1, k_2, and k_3 depend on the design adopted for the tanks, on the amount of floor-space provided, on the style of building, on the leads, on the maintenance expenses, &c. The following table gives, in detail, the various heads of expenditure, both as regards first cost, maintenance, and working expenses, and the above factors have been worked out for an average case. Although the *actual* values of these factors will vary, according to the circumstances of each installation, the *relative* values will not, it is thought, be materially altered.

Daily Cost of Activity.—The daily cost of activity, which will be expressed by A, depends on the size of the installation, on the class of boiler, engine, and dynamo used, on whether water power is available, on the number of hours worked per diem, &c. Under this head must also be included the cost of the apparatus required to keep the solution in motion. The daily cost of activity depends to a certain extent on the commercial efficiency of the dynamo; and, in so far as this efficiency depends on the strength of the current, this item of expenditure will vary. But the variation, if any, is small, so that, remembering that the watts are constant, it can be assumed that the cost of activity is constant.

Daily Cost of Superintendence.—This item depends principally on the size of the installation, and can be regarded as constant

for any particular installation; it will be expressed by B, and is taken to include all general expenses.

TABLE SHOWING COST OF DEPOSITING TANKS.

Items of Expenditure.	k	k_1	k_2	k_3	Cost when S = 100.	Cost when S = 1,000.
					Pence.	Pence.
Framework*	160	$\frac{390}{100}$	$-\frac{5}{100^2}$	...	545	3,560
Lining	136	$\frac{200}{100}$	...	...	336	2.136
Apparatus for moving solution	60	$\frac{100}{100}$	...	...	160	1,060
Arrangement for keeping plates separate	...	$\frac{150}{100}$	...	...	150	1,500
Anodes	...	$\frac{4000}{100}$	...	...	4,000	40,000
Solution	...	$\frac{960}{100}$	...	...	960	9,600
Leads	...	$\frac{120}{100}$	$\frac{320}{100^2}$	$\frac{23}{100^3}$	463	56,200
Connections of leads to plates	...	$\frac{240}{100}$	...	...	240	2,400
Switch	...	$\frac{500}{100}$	$-\frac{23}{100^2}$	$\frac{0{\cdot}5}{100^3}$	477	3,200
Fitting up	...	$\frac{120}{100}$	$\frac{1}{100^2}$	...	121	1,300
Building	564	$\frac{1260}{100}$	$-\frac{0{\cdot}6}{100^2}$	...	1,824	13,104
Total	920	$\frac{8040}{100}$	$\frac{291{\cdot}4}{100^2}$	$\frac{23{\cdot}5}{100^3}$		
Say 10°/o for interest and depreciation ...	92	$\frac{804}{100}$	$\frac{29{\cdot}1}{100^2}$	$\frac{2{\cdot}35}{100^3}$		
Divide by 310 working days, for daily cost	0·3	$\frac{2{\cdot}6}{100}$	$\frac{0{\cdot}094}{100^2}$	$\frac{0{\cdot}0076}{100^3}$	3·0	43·3
Working expenses—including rent, insurance, &c.	...	$\frac{3{\cdot}5}{100}$	...	...	3·5	35·0
Total	0·3	$\frac{6{\cdot}1}{100}$	$\frac{0{\cdot}094}{100^2}$	$\frac{0{\cdot}0076}{100^3}$	6·5	78·3
	k	k_1'	k_2	k_3	$\phi(100)$	$\phi(1{,}000)$

* Supposed to be made of wood. Size, when S = 100, 5′ 0″ × 2′ 6″ × 3′ 0″.

Weight of Copper Deposited.—It is known that one ampère

will deposit $\frac{1}{384}$ lbs. of copper per hour, so that the weight of copper deposited in each tank per hour is

$$\frac{\gamma S}{384},$$

and therefore, if work is carried on for T hours per diem, the total weight of copper deposited in the n tanks per diem will be

$$\frac{n \gamma S}{384} \cdot T.$$

Hence, finally, if U is the cost of depositing *one* lb. of copper

$$U = \frac{384}{T} \cdot \frac{n \phi (S) + A + B}{n \gamma S} \cdot \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

This equation, combined with equation (1) and differentiated in the usual way to obtain a minimum value, gives, after some reduction,

$$S \left(\frac{r}{r + \frac{\epsilon}{\gamma}} (A + B) - n \phi (S) \right) D \gamma$$

$$+ n \gamma \Big(S \phi^1 (S) - \phi (S) \Big) DS = o;$$

and, equating the coefficients of $D \gamma$ and DS to zero,

$$n = \frac{r}{r + \frac{\epsilon}{\gamma}} \cdot \frac{A + B}{\phi (S)} \quad \ldots \quad \ldots \quad (3)$$

and

$$S = \frac{\phi (S)}{\phi^1 (S)} \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

and the values of n, γ, and S, which satisfy equations (1), (3), and (4), are those which make U a minimum.

A complete solution would be too complicated for practical use, but an approximate solution can be obtained, as follows:—

For equation (3) the following average values can be assigned:

$$r = 0{\cdot}15 \text{ ohm},$$
$$\epsilon = 0{\cdot}02 \text{ volt},$$

and, as it is unlikely that γ will be less than 3 ampères per square foot, in practice the smallest value of $\frac{r}{r + \frac{\epsilon}{\gamma}}$ is, under these conditions, 0·96.

Therefore, as a first approximation,

$$n_1 = \frac{A + B}{\phi\,(S)} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

or,

$$n_1 = \frac{\text{daily cost of activity + daily cost of superintendence, etc.}}{\text{daily cost of one tank.}}$$

Returning to equation (4), and substituting for ϕ (S) and ϕ^1 (S) their values, namely,

$$\phi\,(S) = k + k_1\,S + k_2\,S^2 + k_3\,S^3$$

and

$$\phi^1\,(S) = k_1 + 2\,k_2\,S + 3\,k_3\,S^2,$$

it will be found that

$$k_2\,S^2 + 2\,k_3\,S^3 = k.$$

For instance, taking the values of k, k_2, and k_3, given in Table I., it will be found that

$$S = 160 \text{ sq. ft.}$$

It will be observed that the value of S, which makes U a minimum, is dependent only on the factors k, k_2, and k_3, and is independent of the factor k_1, and also of n, γ, and CV. It follows that the size of the tanks in which copper can be deposited at a minimum cost is independent of the size of the installation, and depends only on the design adopted for the tanks, and on the proportion of energy wasted in the leads.

Within certain limits, however, the value of S has but little influence on the value of U, as will now be shown.

In equation (1) the term $n\,\epsilon\,\gamma\,S$ is comparatively small, as will be seen on referring to the values previously given for r, ϵ, and γ, and therefore, approximately,

$$n\,r\,\gamma^2\,S = (1 - a)\,CV \quad \ldots \quad \ldots \quad (6)$$

Combining this equation with equations (2) and (5), and reducing, it will be found that, *approximately*,

$$U = \frac{768}{T}\left(\frac{(A + B)\,r}{(1 - a)CV} \cdot \frac{\phi\,(S)}{S}\right)^{\frac{1}{2}} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

$$= \frac{768}{T}\left(\frac{(A + B)\,r}{(1 - a)\,CV}\right)^{\frac{1}{2}} \cdot \left(\frac{k}{S} + k_1 + k_2\,S + k_3\,S^2\right)^{\frac{1}{2}}$$

Now, having regard to the values of k, k_1, k_2, and k_3, given in the Table, it will be seen that for small values of S, U is large, and, at first, as S increases U diminishes, but that when S lies between

certain limits the value of U alters very little—beyond the upper limit U increases gradually as S increases. This result is clearly shown by the curve, Fig. 1, and it will be found that from S = 160 to S = 100, and from S = 160 to S = 250, the value of U only increases 1 per cent.

Further, if the values of k, k_2, and k_3 were doubled, k_1 remaining constant, the corresponding limits for S would be 105 and 240 square feet; and if k, k_2, and k_3 were halved, the limits would be 65 and 360 square feet.

Making, therefore, every allowance for inaccuracies in the estimates by means of which the values of the factors k, k_1, k_2, and k_3 were obtained, and for the effect of various designs and circumstances (and it is to be observed that these limits of S depend on the *relative* values of the factors, and not on their absolute values), it would appear that any value of S lying between the limits of 100 and 250 square feet can be chosen without practically increasing the cost of depositing from the absolute minimum.

Having therefore selected some suitable value for S lying between the above limits, the daily cost of *one* tank *i.e.*, ϕ (S)—can be found, and to do this it is unnecessary to find k, k_1, k_2, k_3, but an ordinary estimate of the cost is all that is required. n_1 can then be obtained from equation (5), and then γ_1, with sufficient approximation, from equation (6). Substituting in equation (3) the value of n is obtained, and then a more accurate value for γ. It is assumed, of course, that A, B, r, and ϵ are known.

So far it has been assumed that the tanks are arranged in simple series; it remains to be seen whether anything is gained, or otherwise, by grouping a number of the tanks in parallel and placing these groups in series.

Electrically, each group can be looked upon as if it were *one* tank, having a cathode surface equal to the sum of the cathode areas of all the tanks in the group. Thus, if there be m tanks in each group, each tank having a cathode surface of S square feet, each group can be regarded as *one* tank having a cathode surface of m S square feet; and, if the additional leads required to

connect the groups together are for the moment neglected, it is clear that the daily cost of the group will be $m\,\phi$ (S). Hence, applying equation (7),

$$U = \frac{768}{T}\left\{\frac{(A+B)r}{(1-a)CV} \cdot \frac{m\,\phi(S)}{m\,S}\right\}^{\frac{1}{2}}$$

or, with the proviso relative to the leads, the cost is the same as if the tanks were placed in series. But the additional leads required to connect the groups will cause additional expense by the energy wasted in them, and by the increased first cost.

On the whole, therefore, grouping the tanks is not so economical as placing them simply in series. Grouping the tanks entails also the disadvantages of requiring larger currents in the mains, and a greater difficulty in regulating the current per tank.

It remains to be found what proportion of the energy should be wasted in the leads and connections—in other words, what value should be given to the factor a. Following Sir W. Thomson's rule, the leads should be so proportioned that the cost of the energy expended is equal to the interest on first cost and the depreciation. The value of a depends, therefore, on the circumstances of each installation. For example, taking S = 100 and $\gamma = 5$ ampères, CV = 24,000 watts and A = 360 pence, as an average case, it is found that

$$a_1 = \frac{1}{40},$$

and the sectional area of the leads would be about 2 square inches. The leads connecting the dynamo to the tanks were taken into account in finding the above value of a_1, but no allowance was made for switches and connections; adding about one fourth for this purpose,

$$a = \frac{1}{30}.$$

The results arrived at are tabulated below, and it is hoped they may be of practical use.

1. The tanks should be arranged in simple series.

2. The cathode surface per tank for minimum cost of deposition is independent of CV, and can be selected between the limits of 100 and 250 square feet.

3. The number of tanks for minimum cost of deposition can be obtained from

1st approximation,

$$n_1 = \frac{\text{daily cost of activity} + \text{daily cost of superintendence, etc.}}{\text{daily cost of one tank.}}$$

2nd approximation,

$$n = \frac{r}{r + \dfrac{\epsilon}{\gamma}} \, n_1.$$

4. The density of current can then be found approximately from

1st approximation,

$$\gamma_1 = \sqrt{\frac{(1 - a)\,\mathrm{CV}}{n_1\, r\, \mathrm{S}}}.$$

2nd approximation,

$$\gamma = \sqrt{\frac{(1-a)\,\mathrm{CV}}{n\, r\, \mathrm{S}} - \frac{\epsilon\, \gamma_1}{r}}.$$

5. The cost of depositing *one* lb. of copper can be found (approximately) from

$$\underset{(\text{min.})}{\mathrm{U}} = \frac{768}{\mathrm{T}} \left(\frac{(\mathrm{A} + \mathrm{B})\, r}{(1 - a)\,\mathrm{CV}} \cdot \frac{\phi\, \mathrm{S}}{\mathrm{S}} \right)^{\frac{1}{2}}$$

6. The elements for winding the dynamo can then be found, since CV is given and $\mathrm{C} = \gamma\, \mathrm{S}$ is known.

The following numerical examples are appended as illustrations :—

Example No. 1.

Let

$$\begin{aligned}
\mathrm{CV} &= 24{,}000 \text{ watts,} \\
\mathrm{S} &= 100 \text{ square feet,} \\
\phi\,(\mathrm{S}) &= 6{\cdot}5 \text{ pence,} \\
\mathrm{A} &= 360 \text{ pence,} \\
\mathrm{B} &= 50 \text{ pence,} \\
r &= 0{\cdot}15 \text{ ohm,} \\
\epsilon &= 0{\cdot}02 \text{ volt,} \\
a &= \tfrac{1}{30},
\end{aligned}$$

working 10 hours a day;

then

$$n_1 = \frac{360 + 50}{6{\cdot}5} = 63$$

$$\gamma_1 = \sqrt{\frac{(1 - \frac{1}{30})\,24{,}000}{63 \times 0{\cdot}15 \times 100}}$$

$$= 4{\cdot}95 \text{ ampères per square foot;}$$

hence

$$n = \frac{0{\cdot}15}{0{\cdot}15 + \dfrac{0{\cdot}02}{4{\cdot}95}} \times 63$$

$$= 61 \text{ tanks,}$$

$$\gamma = \sqrt{\frac{(1 - \frac{1}{30})\,24{,}000}{61 \times 0{\cdot}15 \times 100} - \frac{0{\cdot}02 \times 4{\cdot}95}{0{\cdot}15}}$$

$$= 4{\cdot}97 \text{ ampères per square foot,}$$

and

$$C = \gamma S = 497 \text{ ampères,}$$

$$V = \frac{24{,}000}{497}$$

$$= 48 \text{ volts.}$$

The cost of depositing *one* lb. of copper will be

$$\underset{(\text{min.})}{U} = \frac{768}{10}\left\{\frac{(360 + 50)\,0{\cdot}15}{(1 - \frac{1}{30})\,24{,}000} \cdot \frac{6{\cdot}5}{100}\right\}^{\frac{1}{2}}$$

$$= 1{\cdot}01\text{d.}$$

The curve marked (1) in Fig. 2 has been drawn to show what effect altering the number of tanks has on the cost of depositing (S remaining constant, and using the data of this example). It will be observed that the cost is a minimum when $n = 61$, and that it increases when n is either increased or diminished. Of course, CV is supposed to be constant, and consequently γ will vary, increasing as n diminishes and *vice versa*. Curve (2) shows the manner in which γ varies. Curve (3) shows the number of pounds of copper deposited per hour for the corresponding values of n. From this curve it appears that the number of pounds of copper deposited per HP. is no criterion of the merits of an installation.

Example No. 2.

Let

$$CV = 24{,}000 \text{ watts,}$$

$$S = 100 \text{ sq. feet,}$$

$$\phi\,(S) = 6{\cdot}5 \text{ pence,}$$

$$A = 200 \text{ pence (water power),}$$

$$B = 50 \text{ pence},$$
$$r = 0{\cdot}15 \text{ ohm},$$
$$e = 0{\cdot}02 \text{ volt},$$
$$a = \tfrac{1}{16},$$

working 10 hours a day;

then
$$n_1 = \frac{200 + 50}{6{\cdot}5} = 38$$

$$\gamma_1 = \sqrt{\frac{(1 - \frac{1}{16})\,24{,}000}{38 \times 0{\cdot}15 \times 100}}$$
$$= 6{\cdot}23 \text{ ampères per sq. foot;}$$

$$n = \frac{0{\cdot}15}{0{\cdot}15 + \dfrac{0{\cdot}02}{6{\cdot}23}} \times 38 = 37;$$

$$\gamma = 6{\cdot}28 \text{ ampères per sq. foot;}$$
$$C = \gamma\, S = 628 \text{ ampères},$$
$$V = \frac{24{,}000}{628} = 38 \text{ volts},$$

$$\underset{\text{(min.)}}{U} = \frac{768}{10}\left\{\frac{(200 + 50)\,0{\cdot}15}{(1 - \frac{1}{16})\,24{,}000} \cdot \frac{6{\cdot}5}{100}\right\}^{\frac{1}{2}}$$
$$= 0{\cdot}8\text{d}.$$

Example No. 3.

Let
$$CV = 4{,}000 \text{ watts},$$
$$S = 100 \text{ sq. feet},$$
$$\phi\,(S) = 6{\cdot}5 \text{ pence},$$
$$A = 70 \text{ pence},$$
$$B = 40 \text{ pence},$$
$$r = 0{\cdot}15 \text{ ohm},$$
$$e = 0{\cdot}02 \text{ volt},$$
$$a = \tfrac{1}{25},$$

working 10 hours a day;

then
$$n_1 = \frac{70 + 40}{6{\cdot}5} = 17$$

$$\gamma_1 = \sqrt{\frac{(1 - \frac{1}{25})\,4{,}000}{17 \times 0{\cdot}15 \times 100}}$$
$$= 3{\cdot}87 \text{ ampères per sq. foot,}$$

$$n = \frac{0{\cdot}15}{0{\cdot}15 + \dfrac{0{\cdot}02}{3{\cdot}8}} = 16$$

and

$$\gamma = 3{\cdot}95 \text{ ampères per sq. foot,}$$
$$C = \gamma\, S = 390 \text{ ampères,}$$
$$V = \frac{4{,}000}{390} = 10{\cdot}1 \text{ volts,}$$
$$\underset{(\text{min.})}{U} = \frac{768}{10}\left\{\frac{(70 + 40)\ 0{\cdot}15}{(1 - \frac{1}{25})\ 4{,}000} \cdot \frac{6{\cdot}5}{100}\right\}^{\frac{1}{2}}$$
$$= 1{\cdot}28\text{d.}$$

The PRESIDENT: I learn that Colonel Stotherd is present, and I shall be glad if he will favour us with his remarks upon Captain Sankey's paper.

therd. Col. R. H. STOTHERD, R.E.: Mr. President and gentlemen,—I am afraid that this paper is too mathematical for me to attempt to criticise, but I will mention what may be of interest to the Society as to the results obtained at Southampton with a dynamo for the electro-deposition of copper. When I went to Southampton in the beginning of 1883, I found that experiments had been instituted with a view to the employment of dynamo electricity instead of Smee batteries in depositing the copper required for duplicates, and what are called matrixes, of engraved copper plates. The result obtained was not satisfactory, but, with the assistance of Captain Sankey, I saw my way to get over the defects and difficulties encountered. The result has been that we have now a very perfect and beautifully working machine for the special purpose required. The copper deposited is far superior, not only in point of appearance, but of uniformity, to what was obtained with the Smee battery, and it is now eminently a success. The whole of the details have been worked out by Captain Sankey, and I think that any information he can give as the result of his experience must be interesting, and will, I think, form a basis to enable those at work on similar operations to fill in the details initiated in the formulæ in his very interesting paper.

nstein. Mr. BERNSTEIN: Mr. President and gentlemen,—The subject of the electro-deposition of copper on a large scale, upon which Captain Sankey has read us some very interesting remarks, is one which has of late been more frequently discussed than in former

8in.

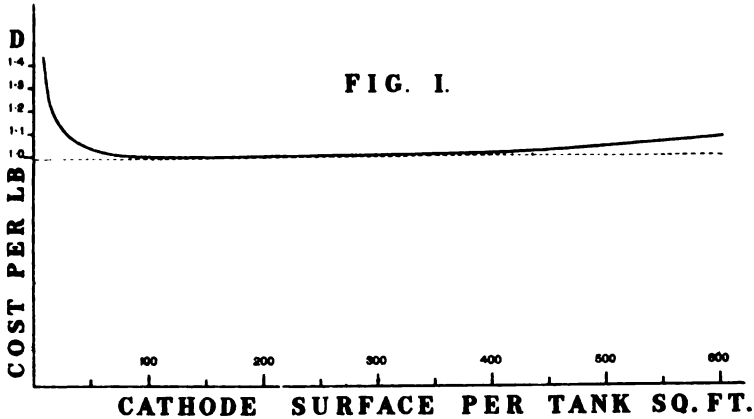


FIG. I.

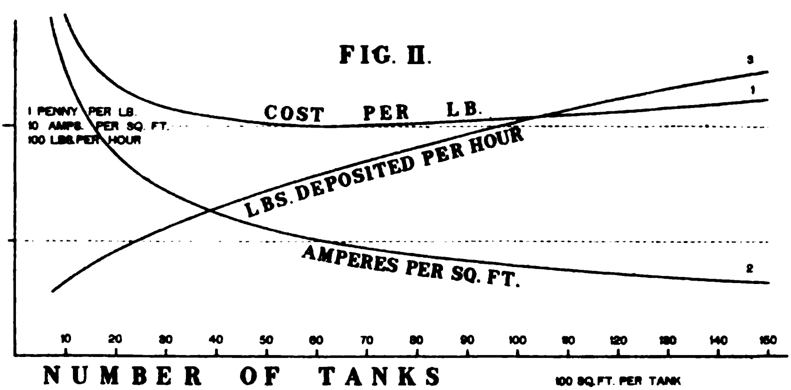


FIG. II.

Col.
Stot

Mr.
Ber

Mr. Bernstein.

years. I suppose that this is due to the fact that a considerable demand for pure copper for electrical purposes has sprung up. As to the remarkable difference exhibited by copper in its electrical resistance if it contains but a small trace of impurity, I have received the following data from one of the largest refiners in Germany:—Metal which contained 99·78 per cent. of pure copper, and whose impurities consisted principally of lead, iron, cobalt, nickel, and arsenic, had an electrical conductivity of 52·16; but if the amount of pure copper rose to 99·97 per cent., the conductivity increased to 60·56. These figures will show the importance of using pure copper for electrical purposes, such as for cables.

In regard to the paper itself, I am inclined to think that the question with which it deals cannot be entirely settled by mathematical calculations. In order to know how copper can be best and most cheaply deposited, it is necessary to know, first of all, for what purpose the copper is to be used. In cases such as Captain Sankey dealt with in a former paper, which he read before the Society some time ago, he had to use a very small current-density in order to produce copper of suitable quality. Even in such cases it is customary to commence with a density of, say, from 3 to 4 ampères per square foot, but to increase this density very much in order to thicken the plates after a thin deposit is made, which ensures the fineness of the reproduction. If the copper is to be used for commercial purposes, it is customary to work with far greater current-densities than any of those which Captain Sankey gets as the result of mathematical calculations. We should think *a priori* that the expense of depositing would always be reduced by using very large current-densities, because we should then want a smaller number of tanks and fewer attendants, and therefore reduce the working expenses; but, on the other hand, there is a limit to the current-density we can use—first, in consideration of the quality of the copper to be obtained, and, secondly, because the large current-density has a tendency to produce a counter E.M.F. which requires more energy in order to overcome it.

Another condition of working which we can alter at our will

is the resistance of the tank. I do not refer here to the question whether the tanks were placed in series or in parallel, because I do not see that the disposition of the tanks in this respect has anything to do with the economy of the electro-deposition; but what I mean is the reduction of resistance which might be obtained by bringing the plates as close together as possible, and, secondly, the possibility of reducing the specific resistance of the solution. When the work is done on a small scale, this reduction is often effected by a slight heating of the solution. I am not aware that this plan has been used when working on a larger scale. It is noteworthy that the resistance of copper sulphate decreases very greatly when only very slightly increased in temperature.

I think that these few remarks will be sufficient to explain my meaning when I said in the beginning, that the problem with which we have dealt here cannot be solved by mathematical calculation alone, although we certainly are much indebted to Captain Sankey for his very interesting attempt in this direction.

Professor G. FORBES: I am sure no one present will imagine for a moment that I am not always perfectly willing to support the desirability of reducing our estimates to mathematical accuracy so far as is possible, on every occasion, but I am sure I most heartily agree with what has fallen from Mr. Bernstein as to the almost impossibility of reducing this question, under present circumstances, to the mathematical perfection which Captain Sankey has suggested. First, the number of data is so very great that it is simply impossible to arrive at a general formula which will include every case. We have not before us the data which the author used to compute his constants, so we cannot criticise them, but Captain Sankey has himself alluded to the great difficulty which he had in forming estimates and in finding out the different values of these quantities, and I can tell him that there are very many more points to be taken into account than he has actually considered. My own experience in this matter has been connected with depositing for totally different purposes, and on a very much larger scale than that which Captain Sankey has in mind—something like 24,000 watts at the

Professor Forbes.

most. The greatest depositing which I have been connected with has been in the Swansea works of Mr. Lambert, where conditions are introduced which are totally different from such cases as depositing plates for printing the engraved survey. The object at Swansea is not to get the copper which is deposited, but to get the silver and gold that is in the auriferous and argentiferous copper ores, and in that process there are numbers of points that come into the question which are not provided for in Captain Sankey's calculation. I will mention one. What is the capital lying in anodes? How can we compare the thin plates of Captain Sankey with the 1½-inch plates of Mr. Lambert? This is the most important item of all, and is absolutely uncertain. How does Captain Sankey estimate this? Again, what distance are the smelting works from the tanks, and what labour is required in fixing the anodes in the tanks? Also, a comparison is made between a large number of tanks in series and a small number. From an examination that I made at Messrs. Lambert's works, of the expense of working there, I came to the conclusion that, if we had the machine ready, the most econonomical and satisfactory way of working was with one single tank and a very low electro-motive force indeed. Looking at figure 2, though it is impossible to say with certainty, I can hardly think that the cost per lb. would rise in the manner indicated in the top curve, which has been carried out to only 60 tanks. If, as I say, it should be reduced to one tank, and the current were continued, the cost would be 20, 30, or 50 times what it would be when employing the 60 tanks. I am perfectly sure that that result is false, and that the mathematics employed in it do not apply to the employment of a single tank. It was seeing the importance, at the Swansea works, of having a large current and a single tank that has encouraged me to continue in the design and construction of a large dynamo without any commutator, and with no self-induction, which shall give any quantity of electricity that is desired at the very lowest electro-motive force that can be wanted. I am quite sure that the future of such a machine and its applications will be enormous. At the present moment the only practical application of depositing copper is, as I have said,

ofessor rbes. in the extraction of gold and silver from copper ores; in the future, I may say with confidence that before long, as soon as large tanks and single machines are used, manufacturers will be able to deposit copper kettles and pans at a cost of a very few pence per lb., whereas, at the present moment, it takes about eighteenpence or more to manufacture them. There is not the slightest doubt that that is one of the applications that will come. Further, I can see that one of the first applications with the large current which we now know can be realised will be the coppering of ship's bottoms. I do not know if Captain Sankey will think that we ought to copper ship's bottoms in series of sixties!

The PRESIDENT called upon Captain Sankey to reply.

pt. nkey. Capt. H. R. SANKEY, R.E.: I am sorry there have been so few speakers, and I am afraid that both Mr. Bernstein and Professor Forbes have rather missed the point of my paper. It was stated to be a problem, and I worked that problem out in the best way I could. It does not by any means attempt to be a solution of the whole question of the economical deposition of copper; and the values I have given for r and ϵ are simply average values, given to be able to work out a numerical example, so that some sort of idea of the results obtained can be formed. Undoubtedly the general question of finding the best arrangement for depositing copper on a large scale cannot be settled by a simple mathematical formula, and must be arrived at by a series of approximations. I think, however, the results arrived at in this paper, as regards the best size for the tanks and the best number of tanks, may be of use in the general investigation.

As regards Mr. Bernstein's remark about the conductivity of copper increasing so rapidly with a small diminution of impurity, I may mention, although apart from the subject, that I had occasion to test a sample of copper sent by a firm, in Hughes's induction balance, and it gave me a reading of 200· on the scale. I informed the firm that the metal was not so pure as some sent on a former occasion; they replied that it contained 99·5 per cent. of copper, but they had some which contained 99·9 per cent.—a sample of which was sent and gave a reading of 262·. On the previous occasion referred to the reading was 260·.

Capt. Sankey.

I fail to see how a large current-density can be economical, as stated by Mr. Bernstein. A reference to the curve No. 3, in Fig. 2, shows that as the density of current increases beyond about 8 ampères the cost increases rapidly. And I think the reason is very evident; with a large density of current there must necessarily be a small cathode surface, always supposing that the dynamo is of the same power—that is the basis on which the paper rests—and consequently only a small quantity of copper is deposited per hour; the expense of depositing must therefore be great.

I purposely did not mention anything about the limits of the density of current, because that varies very much according to the purpose for which the copper is required. At Ordnance Survey, Southampton, where the deposited copper is required to be of special quality, I have found that a density of 6·5 to 7· ampères per square foot is beginning to be a little too much, but I do not say for a moment that that is too great a density when the quality of the copper is not a matter of great importance.

With reference to Professor Forbes's contention that a single tank is the cheapest arrangement, it will be observed, on referring to the Table, that as regards the cost of the tank itself, the larger the tank the cheaper it becomes, but that the leads bring up the expense, at any rate, on the assumption made in the paper that the loss of energy in the leads should be constant. To make sure that this assumption is correct I worked out a case, taking $S=1,000$ square feet. In the first place, according to Sir William Thomson's rule, the leads would have a cross-section of 19·2 square inches. In that case, taking 24,000 watts as the activity of the dynamo, there would be six or seven tanks of 1,000 square feet each, and the energy lost by the leads would amount to nearly 4,000 watts. The daily cost of each tank would be reduced to 70·5 pence instead of 78·3 pence as given on the table, and the cost of depositing one pound of copper, with the remaining data being as per Ex. I., would be 1·11d., which is 11 per cent. more than the cost as worked out in the example. Now, taking the loss of energy in the leads as constant, according to the assumption in the paper, it reduces it to 600· watts (instead of 4,000· watts);

the daily cost of each tank is increased to 78·5d., but the cost of depositing one pound of copper works out precisely the same, viz., 1·11d. Again, taking the leads according to the rule given in "Munro and Jamieson's Pocket-book," namely, one square inch per 1,000 ampères (I do not know whether it is intended that this rule is to go on beyond the table, which only goes up to 1,000 ampères), the loss of energy would be 10,600 watts, and the cost would be increased to 1·19d. The assumption, therefore, appears tenable, and, if so, a number of small tanks in series are more economical than one large tank.

With reference to Prof. Forbes's remark as to the supposed inaccuracy of the curve of cost in Fig. 2, I think there must be some misapprehension, because the tanks in this figure are all supposed to contain 100· square feet. If there was only one tank it would be required to contain 6,000 square feet of cathode surface, which would give a very different result.

Professor FORBES: Yes.

Capt. H. R. SANKEY: I think that I have answered all the points raised on the paper.

I have only to mention that I have brought up three copper plates from Southampton. One is a matrix which has been deposited from the original engraved copper plate; another is a duplicate which has been deposited upon this matrix by means of the Crompton dynamo that we have lately obtained; and the third is also a duplicate which was deposited in the same tank at the same time on another matrix—one of the duplicates is as it came out of the tank, the other has been tempered by being gradually heated by means of a number of gas jets. [*Exhibiting the plate.*] It followed the colours of the rainbow, and at last became quite purple; it was then allowed to cool slowly. The effect of this tempering is to alter in some way or other the arrangement of the molecules of the copper, and it becomes distinctly harder, which is a very important point, as it will last longer for printing. A curious effect has taken place on these duplicates: a bead has been formed all the way round the edge, which is principally due to the matrix being slightly raised at the edges, so that the edges being nearer the

dissolving plate (or anode) they receive more than their fair share of current. In some places, however, the bead is much reduced in size, which is due to the little blocks of wood fastened on to the board which holds the plate, the intention of which is to keep the anode away from the receiving plate, and these blocks, as it were, shadow the current. I would also point out that several of the names on the engraved map can be read on the back of the plate, showing that the deposit has taken place uniformly all over the surface. Capt. Sankey.

I may add that the original plate from which the matrix was taken is worth about £2,000; it took a man four years to engrave it. The cost of producing the matrix and duplicate would be about £5.

A hearty vote of thanks was accorded to Capt. Sankey for his paper.

The PRESIDENT: According to the rules of our Society this meeting closes the first part of the present Session, and under ordinary circumstances we should not meet again until next November. But it is also the custom of our Society that the President should give some kind of a Reception or *Conversazione*; and that custom I am desirous of following some time next month. The date will probably be June 29th, and I shall hope to have the pleasure of seeing you all on that occasion. The President

A ballot took place, at which the following candidates were elected:—

Foreign Members:

Dr. William W. Jacques.
F. A. Lanza.
Professor François Van Rysselberghe.
H. Serrin.

Member:

Sir James N. Douglass.

Associates:

Hans E. B. Atkinson.
James Brayshaw.
Arthur W. Coulson.
James Douglas Dallas.
Frederick J. Down.
Léon Drugman.
A. J. Lawson.
Robert Hansford Mance.

Associates—continued.

George S. Noble.
Samuel Spence Parkyn.
Charles John Robertson.
George Henry Robertson.
Henry Mannington Sayers.
T. F. Toft.
Charles Wilson.
H. Wood.

Students:

Charles Alfred Baker.
Harold Reade Braid.
James Edward Burton.
Frederick W. M. Chapman.
William Foreman Collins.
Sidney F. Ellis.
Charles S. D. Fisher.
Edgar T. Gideon.
Charles Henry Hill.
Louis Campbell Login.
Frank Albert Newton.
Reginald Staddon Pearse.
John Rance, jun.
Bertram Thomas.
Eustace Thomas.
Ernest George Tidd.
Francis Lovell Todd.

The meeting then adjourned.

THE LIBRARY.

ACCESSIONS TO THE LIBRARY TO JULY 26, 1886.

By Alfred J. Frost, *Librarian.*

(Works marked thus (*) have been purchased.)

IT IS PARTICULARLY DESIRABLE THAT MEMBERS SHOULD FORWARD COPIES OF THEIR WORKS TO THE LIBRARY AS SOON AS POSSIBLE AFTER PUBLICATION.

Abel and Imray. Patents, Designs, and Trade Marks, British and Foreign. An Outline of Laws and Procedure relative to Patents, Designs, and Trade Marks. 8vo. 126 pp. *London*, 1886
[Presented by Harold Imray, Esq.]

Bardet [Dr. G.] Traité Élémentaire et Pratique d'Électricité Médicale. Précédé d'une Préface de M. C. M. Gariel. 8vo. 645 pp. *Paris*, 1884
[Presented by Prof. D. E. Hughes, F.R.S., President.]

Bianchi [Nicomede.] Carlo Matteucci e l'Italia del suo tempo. 8vo. 595 pp. *Torino*, 1874
[Presented by Prof. D. E. Hughes, F.R.S., President.]

* **Boulanger** [J.] Sur les Progrès de la Science Électrique et les Nouvelles Machines d'Induction. 8vo. 178 pp. *Paris*, 1885

Ewing [Prof. J. A.] Experimental Researches in Magnetism. 4to. 117 pp. Plates. [*Phil. Trans. Roy. Soc.*, Part II., 1885.] *London*, 1885

Ferrers [N. M.] [*Vide* Green, Geo.]

Gariel. [*Vide* Bardet.]

* **Green** [George]. Mathematical Papers of the late George Green. Edited by N. M. Ferrers, M.A. 8vo. 336 pp. *London*, 1871

Houston [Prof. Edwin J.] Some Additional Facts concerning the Reis Articulating Telephone. 8vo. 6 pp. [Reprinted from the *Journal of the Franklin Institute*, July, 1886.] *Philadelphia*, 1886

Imray. [*Vide* Abel and Imray].

Institution of Civil Engineers. Minutes of Proceedings. Vol. LXXXIV. 8vo. 574 pp. Plates. *London*, 1886

International Inventions Exhibition. Official Catalogue for Jury. 8vo. 368 pp. *London*, 1885
[Presented by Prof. D. E. Hughes, F.R.S., President.]

Kapp [Gisbert]. Electric Transmission of Energy, and its Transformation, Subdivision, and Distribution. 8vo. 331 pp. [The Specialists' Series.] *London*, 1886

La Touanne [G. De]. Etablissement d'une Communication Téléphonique entre Paris et Reims a l'aide des Conducteurs Télégraphiques existants. 8vo. 36 pp. [Ext. des *Annales Télégraphiques*, Jan.—Fev., 1886.] *Paris*, 1886

* **Mathieu** [Emile]. Théorie du Potentiel et ses Applications à l'Électrostatique et au Magnétisme. 4to. Premier Partie, Théorie du Potentiel, 179 pp. Seconde Partie, Electrostatique et Magnétisme, 235 pp. *Paris*, 1885–86

Matteucci [C.] [*Vide* Bianchi.]

Reichenbach [C.] On some Properties of the Earth. 8vo. 376 pp. *London*, 1880

[Presented by Prof. D. E. Hughes, F.R.S., President.]

Reis. [*Vide* Houston.]

Royal Society. Philosophical Transactions. Vol. CLXXI., Part I., to Vol. CLXXV., Part II. 15 vols. La. 4to. *London*, 1880–85

[Presented by Prof. D. E. Hughes, F.R.S., President.]

* **Schoentjes** [H.] L'Electricité et ses Applications. 8vo. 488 pp. *Paris*, 1886

Smithsonian Institution. Annual Report of the Board of Regents, showing the Operations, Expenditures, and Condition of the Institution for the Year 1884. 8vo. 904 pp. *Washington*, 1885

[Exchange.]

Society of Engineers. Transactions for 1885. 8vo. 211 pp. *London*, 1886

[Exchange.]

Société Scientifique Industrielle de Marseille. Bulletin. Année 1884. 8vo. 262 pp. *Marseille*, 1884

[Exchange.]

——— Bulletin. Année 1885. Troisième et Quatrième Trimestres. 8vo. 381 pp. *Marseille*, 1885

[Exchange.]

Swinton [Alan A. C.] The Elementary Principles of Electric Lighting. 8vo. 32 pp. *London*, 1886

ORIGINAL COMMUNICATIONS.

GOTT'S FAULT SEARCHER.

About nine years ago Mr. John Gott, then of St. Pierre, Miquelon, published to the world, through the journal of our Society, an account of an exceedingly ingenious invention of his, which he termed "wire finder," which will be found on page 522 of Vol. VI., 1877, and on page 77 of Vol. VII., 1878.

Mr Gott has, since then, entirely altered the construction of the wire finder, and, after an enormous number of experiments to discover the best possible practical shape, dimensions, quantity, and gauge of wire, &c., has succeeded in manufacturing what I believe to be the most sensitive current-detector ever yet made.

Many of the thousand and one cases in which this instrument will be found useful must suggest themselves to the practical electrician, but one application in particular, is, I think, well worthy of especial notice.

When picking up a cable for the purpose of discovering and removing a fault, it is usual to cut the cable every now and then, when the fault is believed to be near the ship, in order to ascertain whether the defect is already in board or not.

Now, to obviate the expenditure of time and cable consequent on such cutting, we use a special form of the instrument above alluded to, which we term a "fault-searcher," by the aid of which, in conjunction with a telephone or other sensitive current-detector, it is easy to determine the moment when the fault comes in board, without cutting the cable and without stopping the ship. The latter, in itself, is a consideration which, I am sure, no telegraph engineer will overlook. The "fault searcher" consists of a large number of turns of insulated wire wound round a frame preferably of semi-circular form. This may be made of gutta-percha, vulcanite, wood, or metal as desired, and may

conveniently be fitted permanently on the ship in such a position that the cable shall, in passing from the bows in board, be made to pass over and very close to that part of the frame which may be termed the diameter. The ends of the wire wound round the frame are connected by two wires to a telephone or other sensitive current-detector which may conveniently be placed in the testing room, or in any other cabin in which comparative stillness can be obtained.

It will be seen that if we set up in the cable a current rapidly changing in direction or intensity, the detector, in connection with the fault searcher, will indicate such change.

According to the circumstances of the case, the passage of current through the cable may be regulated at either the shore or the ship end. In either case the other end of the cable should be left perfectly dry and free.

The "fault searcher" can be made in multitudinous forms, and might, if required, be fitted to a drum or to the bow sheave, in which cases, rubbing contacts would have to be established for connection with the current-detector.

The "fault searcher" will be found exceedingly useful in nearly all cases of fault localisation, and also for discovering the whereabouts of buried wires, particularly shore ends of cables.

I might mention here that in order to ensure the perfect dryness and insulation of the end of the cable, we place on the latter a cap composed preferably of india-rubber. This cap resembles in form a cork, but the axis is hollow to within, say, half-an-inch from one end. The hole has a series of deep threads throughout its length. Between each thread, therefore, there is a projecting ring, which offers a new obstacle to the penetration of moisture. Such a terminal insulator will be found of great use also in all cases where the end, which it is desired to leave free and dry, is liable to contact with extraneous substances or to become moist through the humidity of the atmosphere or other causes. It is easy to make a cork which would form a perfect seal for the cable end, even should the latter be plunged under water.

As will, of course, be readily seen, under many conditions the "fault searcher" might be used for the purpose of reading messages

passing through a cable without cutting the latter. But the uses to which the instrument can be very profitably employed are so numerous that I will not enter any further into the matter, merely remarking that, in cases where quantitative accuracy is required, Professor Hughes's sonometer may, with great advantage, be used with the fault searcher. I regret that Mr. Gott is absent from England, and that his time is so fully occupied that the task of writing on the subject of this invention has devolved upon me.

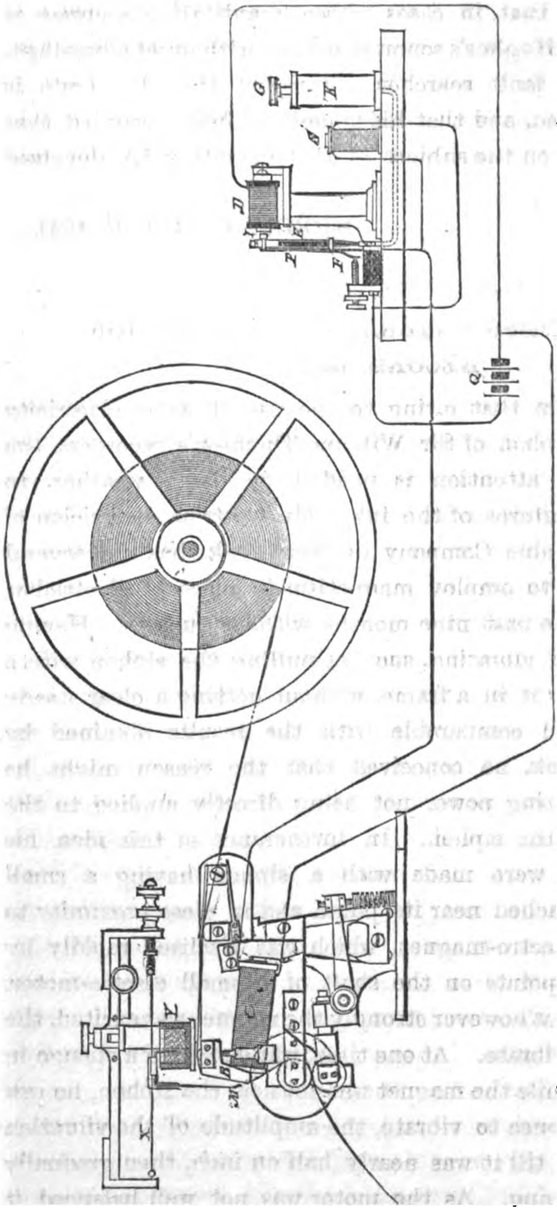
HERBERT KINGSFORD.

May 16*th*, 1886.

THE CUTTRISS "VIBRATOR" FOR SIPHON RECORDERS.

It is well known that owing to the use of static electricity for vibrating the siphon of Sir William Thomson's recorders, the greatest care and attention is needed, in damp weather, to prevent frequent failures of the ink. Mr. Cuttriss, electrician of the Commercial Cable Company in New York, has for several years endeavoured to employ magnetism in place of electricity, but until within the past nine months without success. Having tried many ways of vibrating, such as pulling the siphon with a thread, and rocking it in a frame, without getting a clear steady line, or one at all comparable with the results obtained by electrifying the ink, he conceived that the reason might be owing to the vibrating power not being directly applied to the marking point of the siphon. In furtherance of this idea, his next experiments were made with a siphon having a small particle of iron attached near its point, and in close proximity to one pole of an electro-magnet, which was vitalised rapidly by arranging contact-points on the shaft of a small electro-motor. But it was found that however strongly the magnet was excited, the siphon would not vibrate. At one time, while making a change in the battery, and while the magnet was not near the siphon, he saw it suddenly commence to vibrate, the amplitude of the vibration steadily increasing till it was nearly half an inch, then gradually dying down to nothing. As the motor was not well balanced, it

was thought that the table might have vibrated together with the siphon and its suspension; and, as one end of the siphon was hanging free like a pendulum, when the table vibrated at a rate



equal to the natural rate of the siphon, the latter also took up the vibration, and by its inertia the movements were made apparent. The appreciation of this fact solved the whole difficulty, for it was then found (after the motor had been moved to another table and the magnet replaced at the point of the siphon) at a certain speed a perfectly steady movement of the siphon could be obtained at a rate of about 90 full vibrations per second. The next step was to construct an adjustable vibrator or contact - maker, and after trying various devices he

at last settled down to one on which variations of temperature seem to have no appreciable effect. It is constructed as follows:— A steel rod (*P*) to which is attached an armature (*I*) and contact-point (*F*), as in any ordinary rheotome, supports a glass tube (*E*) $\frac{1}{8}$ inch bore and about four inches long; connected with this tube by a small one of flexible india-rubber is a reservoir of mercury (*K*) fitted with a plunger. By depressing the plunger (*G*), which is fitted with a regulating screw, the mercury can be forced and maintained in the glass tube at any desired height, thereby adding weight to it, which slows the speed to any degree required.

The great advantage of this device is that the pressure on the contact-points always remains the same whatever the speed of the tube may be, and they therefore never require re-adjusting.

To adapt this system to any of Sir William Thomson's recorders, all that is required is to replace the ordinary sliding paper guide and siphon table with one (*B*) which has a piece of iron about $\frac{3}{4}$ inch long and $\frac{1}{4}$ inch wide let into the siphon table across and flush with its face, at such a position that the point of the siphon (*M*) hangs opposite to it. To the back of this piece of iron is fastened a bar electro-magnet (*C*) 3 inches long, and to the siphon a small particle $\frac{3}{32}$ of an inch long of No. 32 iron wire must be attached at a distance of $\frac{1}{16}$ of an inch from the marking point. If now one of the adjustable vibrators running with 3 cells of gravity battery (*Q*) is connected to the bar electro-magnet of the magnetic table, and the mercury in the reservoir be gently forced into the glass tube of the vibrator, the siphon will be seen to vibrate as perfectly and steadily as with electrified ink. With the magnetic table is supplied a small permanent steel magnet, which is also attached to the sliding frame; one pole of it is arranged so as to come within about $\frac{1}{8}$ inch of the siphon. By its influence any slight irregularity of the contact-maker does not affect the uniform working of the siphon.

For the past three months this vibrator has been in use on the Commercial Cable Co.'s section between Canso (Nova Scotia) and New York—length, 840 knots—and also for a shorter period on

one of the main sections of the same company's cables between Waterville (Ireland) and Canso—length, 2,340 knots. On both cables the vibrator has worked so satisfactorily that the Company has given orders that instruments be made and fitted to all the recorders employed on its system.

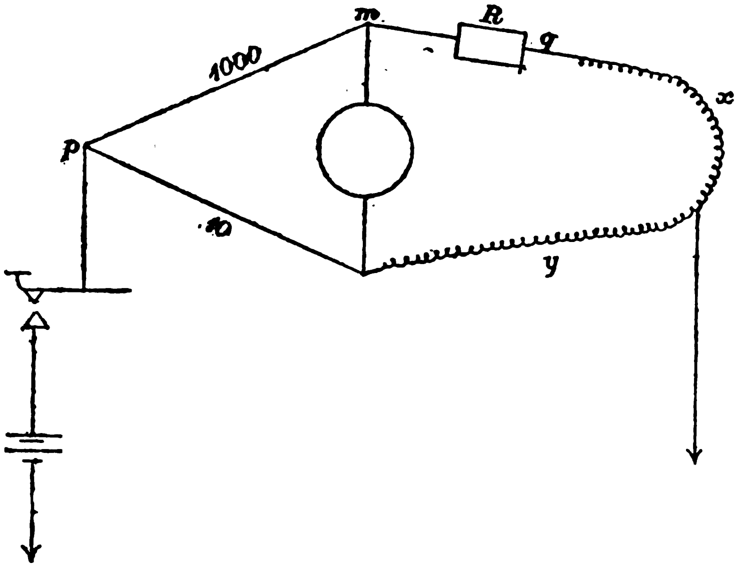
GEO. G. WARD,
Local Hon. Secretary.

NEW YORK, *July 13th*, 1886.

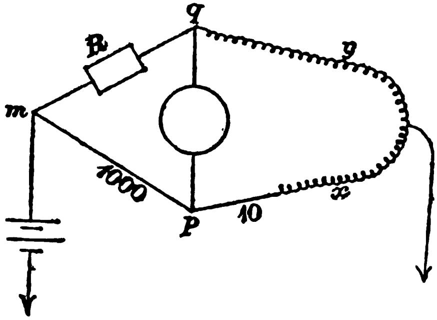
A MODIFICATION OF THE ORDINARY LOOP TEST FOR LOCALISING FAULTS OF HIGH RESISTANCE IN SHORT CABLES.

In Vol. IX. of the Journal a mode of localising faults in cables where both ends are attainable, is suggested by Mr. H. Kingsford, in which the branch resistances are not kept equal, but arranged in the proportion of 1,000 to 10. By interchanging the ends of the cable he is thus able to get two values of R at balance, so that he is able to calculate the distance of the fault from either end; the sum of which distances should, after elimination of errors, correspond with the actual length of the cable. This *modus operandi* is no doubt perfectly sound in principle, and I had adopted it previous to reading Mr. Kingsford's article. It was particularly suitable for testing short lengths of G.P. cable, averaging about 300 yards to the ohm, since it enabled me to calculate the fault distance to hundredths of an ohm.

But where the resistance of the fault is very high—say a quarter of a megohm or higher—this plan becomes impracticable, since it will be found that a considerable alteration in the resistance R will scarcely be felt in the galvanometer branch, and consequently it is uncertain at what exact value of R rigid balance is obtained. The reason for this will be clear from a glance at the figure. In the first place, there will be but a very small total current from even 100 cells, the resistance of the fault being so high; of this small current far the greater proportion will flow through $10 + y$, and but a fraction through $1{,}000 + R + x$,



so that the infinitesimal portion that would flow through the galvanometer branch on account of a slight disturbance of balance, would be quite inappreciable even with the most delicate Thomson's galvanometer. But now interchange the positions of R and the smaller branch resistance (and this can be conveniently done with most Wheatstone's bridges by joining the battery to the point m and inserting the galvanometer between the points p and q), and reverse the ends of the cable, and the figure will appear thus:—



It will be clear that the current will divide now where it meets the point m much more equally; and even should the fault have a resistance of a megohm, the galvanometer, if a good one, will answer to every ohm unplugged or plugged in R; so that from the formulæ $1{,}000\ y = (10 + x)\ R$, and, after exchanging the cable ends, $1{,}000\ x = (10 + y)\ R^1$, we are able to calculate the resistances x and y to two places of decimals. A short time ago I tried this method with a cable in the tanks, containing a fault whose resistance varied from 0·5 to 2 megohms. The total length was 3,783 yards, or about 12·61 ohms, and I localised the fault by this method at about 370 yards from one end. Cutting at the 380th yard, the fault was in the shorter piece. I localised again, and made sure of its being within 30 yards of the end where cut, and, again cutting there, found I had eliminated the fault, both ends having a per knot insulation of about 400 megohms, and the 30 yards cut out an absolute insulation of only 2 megohms. On stripping this piece, the fault (a small pinhole in the gutta-percha) was discovered almost exactly half-way, *i.e.*, 365 yards from the original end, so that my localisation was only $\frac{1}{60}$th of an ohm out.

I am aware that this test is something like the "Murray" test, but I think it will be found more trustworthy; at anyrate, nothing could be more satisfactory than its results in the present case, and such accuracy would have been perfectly impossible by the ordinary loop test.

JEFF. J. ALLEN,

Officiating Electrician, Indian Government Telegraphs.

CALCUTTA, *3rd July*, 1886.

To the Editor of the "Journal of the Society of Telegraph-Engineers and Electricians."

18*th June*, 1886.

SIR,—At page 153, line 12, Vol. XV., of the *Journal of the Society of Telegraph-Engineers and Electricians*, after the word "efficiency," the phrase "of the best arrangement possible under the circumstances," ought to be understood. There is, of course,

no limit to the smallness of the efficiency with which it is possible to transmit power; but, in our paper, we suppose the motor to work at the higher of the two potential differences at which it is possible for it to receive the power (see end of Section IX. in the paper). In any case, where power is transmitted through any conductor from a dynamo with a given P.D. at its terminals, if it is found that, as far as the conductor is concerned, the efficiency of transmission is less than $\frac{1}{2}$, then it is possible to improve the arrangement and to transmit the same amount of power from the same dynamo through the same conductor, with an efficiency of transmission which is greater than $\frac{1}{2}$.

Very truly yours,

W. E. AYRTON.
JOHN PERRY.

ABSTRACTS, &c.

RESEARCHES UPON THE SELF-INDUCTION OF AN ELECTRIC CURRENT.

By Professor D. E. Hughes, F.R.S.

Read before the Royal Society, May 27th, 1886.*

Numerous researches have been made upon the self-induction of coils of wire, and but few in relation to the influence exerted by the nature and geometrical sectional form of the electrical conductor when employed in straight wires as in those of a telegraph line with the earth as a return, or those of a single wide loop where the distance of the return wire is sufficient to prevent any appreciable effect from the *mutual induction* of separate portions of the wire upon each other; our present theories class all non-magnetic metals together, taking only into account their specific resistance and the diameter of the wires; they admit, however, a certain modification in magnetic metals due to their magnetic permeability, but we have had but little experimental evidence of the effect produced.

The whole subject seemed to me worthy of experimental investigation, and I have lately* given the results of a first series of experiments made last year. I have remarked since writing that paper many new and important effects, and I have made a new series of researches, the results of which I wish particularly to point out in this paper.

In my late researches I made use of a modified "Wheatstone's bridge," together with a portion of my "induction balance," by means of which the induced or extra currents from the wire under observation were balanced by a secondary current induced from an independent circuit; this gave excellent results, but the method has been criticised as having the fault of not being clear in its indications. In order to meet this objection, and also verify the results which I had previously obtained, I constructed an entirely new bridge, founded upon a most simple and well-known principle, and as the bridge admits of no change in the relative resistance of its sides, its action can be easily understood; it is with this instrument that I have made my new series of experiments.

The instrument consists of an ordinary Wheatstone's bridge, with the exception that a telephone replaces the galvanometer; there are in addition two coils of insulated copper wire, one in each portion of two sides of the

* These Researches being a continuation of those first given in the President's Inaugural Address, January 28th, it has been considered desirable by the Editing Committee to insert this paper *in extenso*.

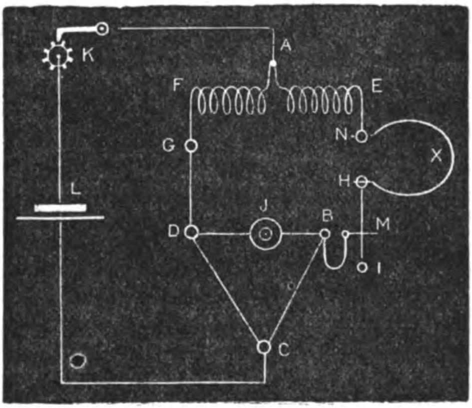
* "Self-induction of an Electric Current in relation to the Nature and Form of its Conductor."—*Journal of the Society of Telegraph-Engineers and Electricians*, January 28, 1886.

bridge, by means of which the mutual self-induction of its convolutions can be increased or decreased as desired.

The electrical contacts are made either by a continuous periodic or tuning fork contact-maker, or by a peculiar clockwork rheotome which I have made, in which a contact spring rests lightly on a wheel whose roughened surface is divided into eight equal parts of contact and insulation, by means of which we receive on the telephone eight equal periods of sound and silence each revolution of the wheel. We are by this means better enabled to appreciate feeble sounds than if they were continuous, and as the wheel can be made to revolve at any between two and ten revolutions per second, we have from sixteen to eighty periods of silence between each rubbing contact per second.

The following figure (1) shows the theoretical plan of the electrical communications of the bridge:—

FIG. 1.



A, B, C, D are the four sides of the bridge, the telephone J replacing the ordinary galvanometer; the sides CB and CD are formed of German silver wire, each 50 cm. in length, 0·5 mm. in diameter, and 0·85 ohm resistance; the sides AB and AD have also 0·85 ohm resistance, so that the four sides have equal resistance, and this remains a constant during the whole series of experiments.

AE and AF is a continuous spiral of copper wire, formed of hard copper silk-covered wire of 1 mm. diameter and 4·80 mètres in length, wound loosely on a boxwood cylinder of 3·50 cm. diameter and 30 cm. in length, on which it moves freely; the entire helix has 40 turns of 4 cm. diameter, each spiral being separated 5 cm. from each other; the spiral, however, is separated into two equal portions by giving a greater separation at the centre in order to allow it to be attached to a sliding collar of wood, by means of which we can press the spiral closer together on either side as desired; at E and F there are also adjustable collars of wood, and as the boxwood cylinder is graduated, we may (if the central collar is fixed) approach more or less either side of the helix, and read the degree of approximation of the coil, thus adjusting the mutual

induction of each side to a perfect balance or zero. In practice I prefer moving the central collar, using the end collars only for the perfect adjustment of its zero, as we then have a double effect, viz., closing the coil, say from A to F, increasing its mutual self-induction, and at the same time decreasing the previously balanced induction of the coil AE—this not only gives a wider range of effect, but renders the scale readings more uniform; the end F of the helix is joined to about 10 cm. of German silver wire, completing the circuit from G to D; this supplementary German silver wire is simply for the purpose of making the resistance of AD equal to DC, and its length should be adjusted to this purpose; the end of the helix E joins directly with the terminal N; the wire to be tested (X) is joined to N and H; from H to I there is a second supplementary German silver wire allowing us by means of the contact side M, which is in direct communication with B, to introduce more or less of the German silver wire in the side AB. The resistance of the wire to be tested should always be less than that of the opposite side of the bridge, and we then make up the total resistance of AB by sliding the contact slide M until the resistance of AB equals AD.

It will be evident that in the whole series of experiments there can be no change in the resistance of either side whenever zero is found, the induction coils or balance having the same proportional current in all the changes of the wires under observation; the battery and telephone circuit present also a continuous absolute relation; we may, however, when desirable, keep the resistance from H to M a constant, and vary the resistance or the length of the German silver wire GD; we then balance the wire X by an equal resistance on the opposite side of the bridge, but then the battery and telephone circuits no longer possess the invariable relations which are so extremely necessary in experiments of the nature of those which I have been making.

The battery circuit is joined in the usual manner to AC, the current can be interrupted by the rheotome K, and by means of a commutator (not shown in the diagram) the battery circuit can be closed, and the contact-maker transferred to the telephone circuit BD; this allows us to observe the effect of an intermittent current compared with that of a constant or steady flow. M. Gaugain has termed the period of a steady flow of current the *stable period*, and that in which a rise or fall of the current takes place the *variable period;* these terms have since been generally adopted by telegraph electricians, and in order to avoid introducing new terms, they will be used in this paper.

It would require too much space to enter into the details of the construction of the bridge—special care is required in the construction of the balancing induction coils, and in securing perfect electrical contacts in all parts of the bridge; the induction balance requires calibration, and for this purpose I introduce as the wire X successive 10 cm. lengths of 1 mm. diameter copper wire, thus forming a table of values throughout the range of the induction balance, or by equal increments of 10 cm. of copper wire up to 20 mètres.

Having no unit of self-induction to which my results could be quickly and practically referred, I have adopted as unit the self-induction of a straight copper wire 1 mm. diameter and 1 mètre in length; this gives on my calibrated

induction scale 100 degrees, and it is to this standard that the comparative force of extra currents mentioned in this paper is compared.

The self-induction of a wire is proportional to its length, consequently a source of error might exist in the different lengths of the supplementary resistance wire HI introduced to balance the resistance of GD, but as we are enabled by the high specific resistance of German silver wire to obtain a very great change in resistance by a comparatively small movement of the sliding scale, this error in most cases of comparative experiments is but a fraction of 1 per cent., and when taken into account as it should be, the error no longer exists.

The telephone used should be of the most perfect kind, and adjusted expressly for rapid and feeble sounds. I have found it best to employ an extremely soft Swedish iron diaphragm, without varnish or anything that can diminish or deaden the sound; its fundamental note should be higher than those generally in use, or at least 500 double vibrations per second, for we have to deal with extremely rapid effects which on short wires cannot be rendered evident upon a galvanometer, but which with a telephone in perfect adjustment are heard most distinctly with an electro-motive force in the battery circuit ranging from 0·001 to 0·250 ampère.

In the sketch of the communications the wire to be tested (X) is shown in the form of a wide loop, but in practice the instrument is constructed on two separate frames of wood articulated together at D, by means of which we can separate the terminals NH, and introduce straight wires, sheets, or tubes of lengths varying from 5 cm. to 1 mètre.

The object of my researches being to observe the self-induction which takes place in straight wires, or in those of a single wide loop, where the reaction from any return wire is at such a distance that its influence is not appreciable, I shall therefore use the term "self-induction" to indicate the effects due to the electric current in its own portion of the wire, and "mutual induction" to those where the reactions of different portions of the current and circuit react on each other, as in the case of coils; and although some theorists consider the two cases as the same, they are, as my experiments prove, entirely distinct, for we have, as will be shown, for copper wires a low coefficient of self-induction with a high mutual induction, whilst in iron wires the reverse is the case, for we there have a high coefficient of self-induction with an extremely feeble coefficient of mutual induction.

Influence of the Nature of the Conductor upon its Self-Induction.

I found, as shown in my late paper, that there was a marked difference in the specific inductive capacity of iron and copper, and this entirely agrees with well-known theories; but I suspected that there might be some difference in the non-magnetic metals independent of their specific resistance. For this purpose I made a series of experiments with wires of the same length and diameter, but of different resistance. These showed a marked difference provided the current was increased in proportion to its diameter or conductivity, but no difference could be found when the current was kept a constant, and the

interior differences in resistance of the wires were compensated by an external added resistance; but if we take wires of different metals—all of the same length and resistance, but of different diameters—there is a marked difference due to the mutual reactions of the current in its own wire, being less in wire of large diameter than in small wires. These effects have been fully explained in my late paper, and have since been completely verified by the method used at present. I showed, by the use of my late method, a critical point in the rise and fall of the induced currents; this is not shown by the present method of compensating by external resistance, but the rapid decrease in the electro-motive force of the induced currents, as indicated by the induction balance, is well shown. The following table shows the observed force of the extra currents for wires of the same length (1 mètre), but of different diameters:—

	mm. 0·25	mm. 0·50	mm. 1·00	mm. 2·00	mm. 3·00	mm. 4·00	mm. 5·00	mm. 6·00	mm. 7·00	mm. 8·00	mm. 9·00	mm. 10·00
Iron ...	760	621	530	360	269	220	190	171	152	138	128	124
Copper	129	113	100	89	82	78	75	73	72	71·5	71·2	71

The fall in force is now even more rapid than shown by my late method, and it will be seen that iron is peculiarly sensitive to an increase in diameter, having nearly six times the force of copper in wires of 0·25 mm., and not twice the force of copper in wires of 10 mm. section.

Reactions of an Electric Current in its own Portion of Conductor.

The phenonemon of a constant decrease in the electro-motive force of self-induction, as measured by the induction balance, with each increase of the sectional area of the conductor, is well shown by the present method, and an experimental investigation of its cause has shown that we should not consider a current in a wire as a single element reacting solely upon exterior wires, but that the current acts precisely similar as would an infinite number of independent streamlets of current reacting upon each other in the interior of its own wire similar to their known effects upon exterior wires. My experiments demonstrate this to a degree that leaves no doubt on my mind as to its truth, for according to this view we should be able to reduce the self-induction to a very great extent by employing thin flat sheets where the outlying portions are at a comparatively great distance from the central portions. This I have experimentally proved to be the fact, but this experiment alone does not show if the reduction of self-induction is due to a different arrangement of the current in sheets as compared with solids. If the reduction is due to the greater separation of the streamlets, then we should be able to reduce this induction in a still greater degree by employing a conductor composed of numerous small copper wires through which the current is equally divided, and which could be separated or brought close together as desired. This proves to be also an experimental fact, for the conductor formed of numerous strands has far less self-induction than a thin sheet when its wires are separated

so that they can no longer react on each other, and surpasses the thin sheet and approaches the value of a circular wire when these wires are brought near together so that their mutual reactions can approximate those of the numerous streamlets in a solid conductor.

Iron shows a still greater reduction in its self-induction when in the form of thin flat sheets or numerous small iron wires separated from each other, with the exception that we cannot restore or approach the value of a solid wire by bringing them in close proximity. The reduction of the induced currents by employing thin sheets instead of a wire is so great in iron that we could not account for it on the mere separation of contiguous portions of the same current, but if we assume that the comparatively high force in iron wires is due to the induced circular magnetism, and that this almost disappears in flat sheets, we account for the fact that a thin flat sheet of iron has less inductive capacity than a similar sheet of copper of the same resistance, but of different widths; and if thin strips of copper, brass, lead, and German silver are compared with similar iron strips, and their resistance rendered equal by the added resistance in the bridge, no difference is found between iron and the non-magnetic metals, for under these conditions their inductive capacities appear equal.

Reactions of an Electric Current between Separate Portions of the same Conductor.

In order to distinguish two distinct effects I have defined self-induction as the effect produced by an electric current on its own portion of the wire, and mutual induction as the effect of the reactions between separate portions of the wire on each other.

The mutual induction in iron and copper wires is very different in degree, as shown by the following table:—

Table I.

Wires, silk-covered, 1 m. in length, 1 mm. in diameter.	Comparative force of the extra currents.	Strips or ribbons, silk-covered, 1 m. in length, 10 cm. wide, 0·1 mm. thick.	Comparative force of the extra currents.
Copper wire, in a single close loop, where each side is in close proximity	18	Copper strip, in a single close loop, where each side is in close proximity	14
Copper wire, in a single wide circular loop ...	100	Copper strip, in a single wide circular loop ...	60
Copper wire, in a coil of 3 cm. diam., having ten layers in close proximity	607	Copper strip, in a coil of 3 cm. diam., having ten layers in close proximity	580
Iron wire (soft), in a single close loop, as above	440	Iron strip (soft), in a single close loop, as above	16
Iron wire, in a single circular wide loop ...	502	Iron strip, in a single circular wide loop ...	60
Iron wire, in a coil, as in the case of copper	570	Iron strip, in a coil, as stated for copper ...	578

There is a remarkable fall in the induction of a straight wire or single wide loop of a copper wire when this wire is doubled upon itself as a return wire in close proximity. The effect of mutual induction is also shown by the equally remarkable rise when the mutual induction of ten layers of a coil react on each other. This is well known, but what I believe has not yet been experimentally observed is the remarkably feeble mutual induction of iron wires, either when in parallel return in close proximity or when in coils of numerous layers; the percentage of increase of induction in a copper wire from a wide single loop to that of the ten layers being 507 per cent., whilst in iron, under precisely the same conditions, there was an increase of but 18·6 per cent.

That this remarkable difference, as shown between the mutual induction of iron and copper wires, is due entirely to the circular magnetism in the iron wire, and that the mutual reactions of the streamlets of the current in a thin flat iron conductor prevent this formation, I have proved in various ways; for, if the circular magnetism is the cause, flat iron sheets which have as low self-induction as copper should be equally sensitive to mutual induction as the non-magnetic metals, for they no longer in any appreciable degree possess the protecting magnetic sheath which enfeebles the mutual reactions of iron wires upon each other; this proves to be the case, a thin ribbon of iron having the same coefficient of mutual induction as copper, and it no longer behaves as a magnetic body.

Table I. shows the difference in the mutual induction of iron wires and strips; it will be seen that when the iron is in the form of a wire, the circular magnetism produces a marked difference between iron and copper, whilst in the form of flat strips the iron resembles copper (as regards mutual induction) in every respect.

Influence of Circular Magnetism.

I have shown in my late paper that an iron conductor composed of numerous fine stranded wires (as in a rope) behaves like copper, and this I regard as entirely due to the breaking up or prevention of circular magnetism; I also showed a phenomenon which I could not then explain, viz., that when an iron wire was heated to a yellow-red heat it lost its previous high specific inductive capacity and behaved like copper. The effect of heat upon magnetism is well known, consequently we can readily explain the fall in its inductive capacity by the disappearance of its circular magnetism. I found also that in thin flat strips of iron there was no change whatever in its inductive capacity at the yellow-red heat; this can now be readily explained: it behaved like copper when cold, and, having but little circular magnetism to destroy, there was no appreciable change produced, except that due to the extra resistance caused by the increased temperature of the strip, and to which copper and iron are almost equally sensitive, consequently we may consider iron (when in the form of thin flat sheets) to behave like non-magnetic metals throughout all temperatures.

Influence of Self-Induction on the Resistance of the Conductor.

A phenomenon of great importance is the effect which I have observed of the resistance of a wire being greater during the rise of the current, as in the

variable period, than that measured or known during the constant flow, as in the stable period; by resistance I mean a pure ohmic resistance—a resistance which can only be measured, expressed, or balanced in ohms, and, whatever the cause, the effect is one of pure ohmic resistance.

We can imagine that at the first moment of contact there is no current flowing through the wire; its resistance is then infinite, but the current gradually increases in force until it arrives at its maximum, as in the stable period. We have thus, between the moment of contact and period of steady flow, a variable period wherein the resistance falls in the form of a curve from infinity to its well-known stable resistance; the telephone is unable to give the exact form of this curve directly, but it gives by the null method comparative results as to the different duration in time of the curve in different metals.

If we take a straight copper wire, 1 mètre in length, and balance its resistance in the stable period, we shall find only traces of a difference in its resistance in the variable period, and we can balance its self-induction by the induction balance; but if we replace the copper by an iron wire of the same length, or even a much shorter wire, viz., 20 cm., we find that in the variable period we can no longer balance the wire by the induction balance alone, but we must compensate for its increased resistance by the sliding scale, the amount of subtracted German silver wire expressing in fractions of ohms (the value of the wire being already known) the additional resistance of the iron wire in the variable period; we can thus reduce or balance the iron wire to a perfect zero, provided the current from the battery does not exceed 0·10 ampère; but with greater current there will still remain a slight muffled sound, which cannot be reduced to zero either by the induction balance or the resistance slide. It therefore became important to determine if this muffled sound was due to a difference in resistance which could not be balanced, or to the lengthened duration of the extra currents being slower than the balancing current from the induction balance; the latter proved to be the case, for, on prolonging the duration of the balancing currents from the induction bridge, by introducing a core of iron in its coil, the balance or zero became absolutely perfect. In this case we must choose between cores of different diameter to find one whose reaction on the time effect of the induction coil, equals the retardation of the extra currents in the wire tested.

If we observe the method employed in the bridge, we shall see that the induction balance can balance the extra current of the wire X, irrespective of the position of the resistance slide M, or any relation between the sides AB and AD, but we cannot equalise the resistance of these sides except by the necessary adjustment of the resistance slide; consequently, when we are forced to adjust the induction balance, we are compensating the extra current, and when we are forced to move the resistance slide we are balancing resistance.

The disturbance in the bridge, caused by the change of resistance of the wire tested in the variable period, causes a momentary primary current to pass through the telephone in the same direction as the extra current, and if these are not separated by balancing the extra current by an induction balance, the mixed effect would be read as a single effect of the extra current. To show

the importance of separating these two effects, it is only necessary to say that in most of the cases cited in this paper the momentary primary current due to the extra resistance greatly exceeds that of the extra current; consequently, all measurements taken wherein this separation is not complete give the result of a mixed effect.

In the method which I have described, the separation of the extra current from the momentary primary current, is so complete that the measures given by the induction balance and resistance slide are invariably the same for a given wire; there is no personal equation, for all observers find precisely the same values both for the resistance and for the extra current.

The method is, however, defective in measuring any small difference of resistance in the variable period in copper wires, as the induction balance itself introduces an additional but opposing resistance by the approaching of its coils, consequently any resistance which we observe is a fraction less than the real amount. To prove this we have only to use a balancing induction current produced from the battery circuit, as shown in my first paper, when we observe this small difference, and better observe any small difference of resistance in a straight copper wire, and any greater when the wire is formed into a coil.

Soft iron wire gives a far higher resistance in the variable period than hard iron, but each wire, according to its molecular structure, has its own value; the effect increases with the diameter, ranging from 25 per cent. increase of resistance, for wires of 2 mm. in diameter, to 500 per cent. for those of 6 cm.

Table II.—Resistance of Iron and Copper in the Stable and Variable Periods.

Wires 1 m. in length, 5 mm. in diameter.	Comparative force of the extra current.	Resistance in ohms, stable period.	Resistance in ohms, variable period.	Percentage of increased resistance in variable period.
Copper	78	0·001284	0·001372	7
Soft Swedish iron ...	234	0·008346	0·022200	166
American compound wire, copper exterior, steel interior ...	83	0·002247	0·002696	20
Ditto, steel exterior, copper interior	213	0·007750	0·024800	220

Table II. shows a few illustrative examples: the resistance is given in the fractions of an ohm, indicated by the resistance slide M upon the supplementary resistance wire HI.

The table shows that copper and the American compound wire coated with copper have an extremely rapid action or curve from an infinite to its stable resistance, due to their freedom from circular magnetism, whilst iron shows a comparatively slow curve. A remarkable result will be seen where a copper wire has been coated with iron, its variable resistance being 220 per

cent. above that of its stable period, and 54 per cent. greater than that of a solid iron wire.

I found, in my previous researches, that the resistance in the variable period could not be changed by a change in speed of a periodic or tuning-fork contact-maker, and that the telephone was more sensitive when the rubbing contacts were used without any regard to their frequency of interval. I also found that the telephone was far more sensitive, and alone suitable for these experiments, when its diaphragm was entirely free from varnish or coating and sufficiently thick to give a clear musical dominant tone of about C or 512 double vibrations per second, the electro-magnet being also as close as possible without being in actual contact. I noticed that, no matter what number of vibrations were sent, the tones given by the telephone on each side of the zero of the bridge were invariably those of its dominant note. Suspecting that the frequency of vibration of the diaphragm had a direct relation with the resistance found, I altered its note, through a range of one octave, by employing different thickness of diaphragms, and found that the results were in absolute proportion to the frequency of the vibrations of the diaphragm; the highest tone giving a perfect zero with a high resistance in the variable period, and the low tone giving its zero at a marked less resistance. Thus it was evident that the telephone selected from the mixed vibrations sent by the transmitter, those which alone corresponded to its period of vibration, and that we could thus observe the effect of more or less rapid periodic contacts.

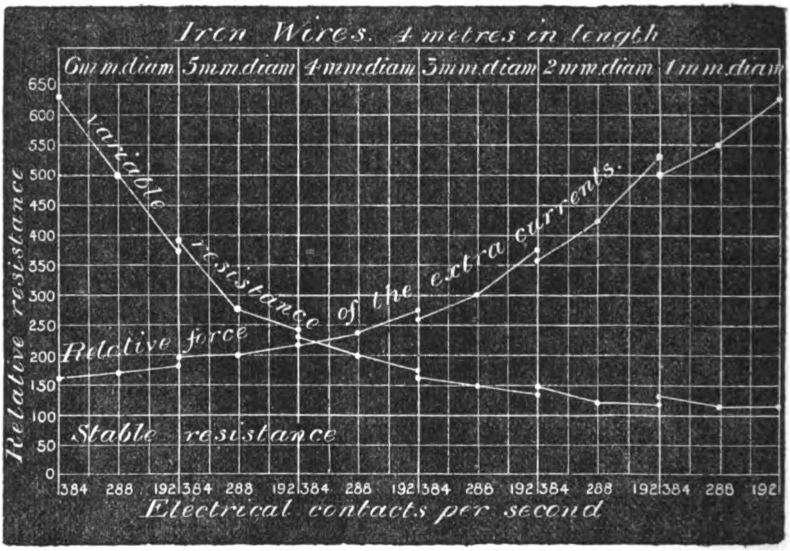
The power which vibrating bodies have of selecting, from a confused number of vibrations, those in accordance with their own, is shown in Helmholtz's resonators; and still more, as regards electrical waves, in the remarkable harmonic telegraph of Elisha Gray, who proved that if the armatures of several electro-magnets are made to vibrate, each with a different musical tone or rate of vibration, then we may, by the use of a vibrating transmitter of a fixed rate of speed, select the electro-magnet alone whose period of vibrations is similar, and that we may send several different periods of vibrations at the same time without any confusion in the receiving magnets, as each electro-magnet selects from the compound vibrations those in accordance with its own. This is exactly what occurs with a telephone when using a periodic contact-maker; but I have found, in addition, that a telephone arranged as I have described will select and respond loudly, in its own clear musical dominant tone, to a confused mass of rapid contacts such as those produced by a scraping contact, and which in an ordinary telephone give only the effect of noise of not one-third the power or loudness of that produced by the tone of the musical telephone. We may thus have ten or more telephones, of different musical notes, each responding separately in its own tone or all at the same time, as each diaphragm selects its own period from the confused periods of contacts sent by the scraping contact-maker.

In order to verify the results, I have used in these experiments both periodic and mixed sound transmitters, but find that, owing to the difficulty of keeping the periodic transmitter and telephone in perfect tune with each other, the mixed sound transmitter is preferable, as it gives no trouble

whatever and we have more accurate results, as we then have only to keep our telephones in accord with the number of vibrations desired.

The experiments mentioned in this paper were all made with a fixed note of vibration of the diaphragm of 512 double vibrations per second. I will, however, mention a few made with varying rates of vibration, and, as I propose in a future paper to give a more extended series of observations through a wider range, I will confine myself to these examples.

Fig. 2.



The diagram (Fig. 2) shows the results obtained on iron wires of different diameters: their stable and variable resistance were all reduced to comparative values, the stable resistance being taken as 100. Three telephones were employed, the first having the musical note of G, or 768 double vibrations; the second C sharp, or 576 double vibrations; and the third one octave below the first, or G, 384 double vibrations per second.

It will be seen that a great change in the variable resistance takes place in the range of a simple octave, and that the fall from the wires of 6 mm. to that of 1 mm. is so regular as to be almost a continuous curve, and the total curve would be probably that taken by the wire of 6 mm. in its approach to its stable resistance. If this is the case, as future researches may show, then the resistance of this wire with the comparatively slow contact speed of six per second would still have 14 per cent. higher resistance in the variable than in the stable period, or an ordinary Morse telegraph instrument, working at a slow speed of only eleven words per minute, would experience this additional resistance; consequently this effect should be easy to prove by the ordinary methods, with galvanometers, and this can be accomplished as soon as we have found a method of completely separating the extra current from that due

to the increased resistance, as I have already succeeded in doing by the method which I have described.

The iron wire of 6 mm. diameter shows, for a speed of 384 contacts per second, a comparative resistance in the variable period of 638, or more than six times its stable resistance, but with 192 contacts per second its resistance is but 371; the fall of resistance is so rapid here that, for a single octave difference in the telephones, the fall is far greater than the whole stable resistance. The extra current, as well known, is proportional to the length of contact for fine wires, but in large wires the curve indicates that the extra currents have a local reaction on the cessation of the primary current.

Influence of a Magnetic Sheath.

The remarkable phenomenon wherein a non-magnetic metal, such as copper, shows a higher "variable" resistance when under the influence of an external coating of iron than a wire of solid iron (and this notwithstanding that the resistance of the side of the bridge is kept a constant or by balancing its resistance on the opposite side GD as mentioned) seemed worthy of experimental research.

Experiments were made in order to find what form of conductor would give the maximum increased resistance in the variable period, and I found that an external tube of iron insulated from its central core produced this effect, for if the tube was not insulated but joined in electrical contact the results were reduced, due, I believe, to a transversal neutralisation taking place in its own portion of the wire, as I have mentioned in my reply to the discussion on my first paper.

Table III.—Influence of an Iron Tube upon an Interior Insulated Wire.

Iron gas tube, 90 cm. in length, 10 cm. diameter, 2 mm. thick. Wires 1 mètre in length, 3 mm. diameter.	Comparative force of the extra currents.	Resistance in ohms, stable period.	Resistance in ohms, variable period.	Percentage of increased resistance in variable period.	Absolute increase of resistance in ohms.
Copper wire alone ...	82	0·00460	0·00482	7	0·00022
Copper wire insulated in the interior of the iron gas tube	410	0·00460	0·03220	600	0·02760
Brass wire, ditto ...	410	0·01380	0·03974	188	0·02594
Iron wire, ditto ...	615	0·02944	0·05888	100	0·02944
Lead wire, ditto ...	410	0·05750	0·08682	51	0·02932
German silver wire, ditto	410	0·07636	0·10384	36	0·02748

Table III. shows the effect produced upon an electric conductor by surrounding it with an insulated sheath of iron. It will be seen that the

magnetic reaction of the tube upon the primary current passing in the wire produces a marked effect upon the different metals; the force of the extra currents, as measured by the induction balance, rise in value from 82 to 410, this being a constant for all metals except iron, which alone shows the higher force of 615; the force of the extra currents, however, has no direct relation to the extra resistance shown in the variable period, but the latter must be in direct relation with the duration or length of time required to pass from an infinite to the stable resistance.

The table shows, on comparing the resistance of a metal in its stable period with that found in the variable, that copper has the highest percentage of increased resistance, being 600 per cent. increase, or seven times that found for its stable resistance, each metal, in the order of their specific resistance, having a less percentage of increased resistance until we arrive at the German silver wire, which shows only 36 per cent. against the 600 per cent. of the copper; we have also here the remarkable fact that iron, even with a circular section, stands simply in its order of specific resistance, showing only one-sixth of the increased resistance experienced by copper; the percentage of increased resistance of a metal when under the influence of an insulated magnetic sheath is directly as its conductivity or inversely as its specific resistance.

If we regard the phenomenon from a different point of view, confining ourselves simply to the additional resistance above that of its specific stable resistance, all metals, whether magnetic or non-magnetic, have an almost invariable quantity dependent entirely upon the coefficient of the electro-magnetic action of the iron tube, and independent of the resistance or nature of the wire.

The experiments with an insulated iron sheath may be considered as a forced condition, which does not occur or need not be taken into account, but the reaction of the iron tube is evidently electro-magnetic, and, as our atmosphere is also magnetic, we may assume that its reaction would be similar, though in a far less degree, to that which I have shown.

Submarine Cables.

The influence of a magnetic sheath upon an external insulated wire is one of vast practical importance in relation to our electrical submarine cables, as they are all constructed with an insulated wire surrounded by a spiral sheath of exterior iron wires. In order to study this question I made several cables of short lengths (1 mètre), and found (most fortunately for our practical applications) that when the exterior iron sheath is divided, as in a cable, or when the sheath consists of several large wires in close contact, its effects are reduced to a mere fraction of what it would be if the external sheath was a continuous tube; this is entirely due (as I have shown in the case of stranded as compared with solid wires) to the imperfect formation of circular magnetism. I will cite a few examples illustrating this. A cable was formed of a similar copper wire and insulation to that shown in Table III., the iron tube being replaced by eight iron wires (of 2 mm. diameter each) wound with a slight spiral of five turns per mètre, this showed but 100 per cent. increase in the force of the extra currents, against 400 per

cent. increase when the same wire was in the iron tube; the increased resistance in the variable period was but 50 per cent., against 600 per cent. for the iron tube, or only one-twelfth of the additional resistance caused by the tube; these wires were replaced by galvanised iron wire, which prevented magnetic contact, and the variable resistance became much less; and when these were replaced by numerous fine iron wires the effect was reduced to the minimum found, or only 20 per cent. increased resistance in the variable period, or 30 times less than that of a solid iron tube of much less iron.

It is therefore evident that the circular magnetism plays an important *rôle*, and that most fortunately our cable manufacturers (without knowing the immense reaction which would be produced by a continuous sheath of iron) have constructed our cables with a protection of iron divided into several iron wires instead of a continuous iron sheath; there are, however, many telegraph lines which, in passing through tunnels, use a continuous iron tube as the protection, and such lines must feel all the deleterious effects that I have shown to be caused by the reaction of circular magnetism.

Influence of Copper and Iron Cores upon the Induction and Resistance of Coils.

It is well known that a coil of wire has a higher self-induction than the same wire in a single loop, and that the coil has a still higher induction when we introduce an iron core. I have made, however, a series of experiments in order to measure the influence of a core upon the resistance in the variable period, and also to note the influence exerted by the induced or eddy currents circulating in the core. The following table shows some comparative results:—

Table IV.

Helix formed of insulated copper wire, 1·50 mètre in length, 2 cm. diameter, and 24 turns.	Comparative force of the extra currents.	Resistance in ohms, stable period.	Resistance in ohms, variable period.	Percentage of increased resistance in variable period.	Absolute increase of resistance in ohms.
Helix alone	460	0·02632	0·02896	10	0·00264
Same, with a core of solid copper ...	352	0·02632	0·04013	52	0·01381
Same, with a core of insulated copper wire	460	0·02632	0·02896	10	0·00264
Same, with a core of solid soft ion	2338	0·02632	0·09870	275	0·07238
Same, with a core of 445 separate fine iron wires, each 0·25 mm. diameter	5360	0·02632	0·04448	69	0·01816
Same, with a core of silk-covered fine insulated iron wires	5820	0·02632	0·04075	55	0·01443

A helix was formed of an insulated silk-covered copper wire of 24 single layers, having an interior diameter of 2 cm., the object being to form a coil having as little mutual induction as possible, but which would be readily acted upon by any core of metal introduced; and, in order to measure the high forces obtained, an induction balance of great power and range was used, the method, however, being the same as that already described.

The helix alone showed an induction value for its extra currents of 460, and a feeble increased resistance in the variable period of but 10 per cent.; if we now introduce a core of solid copper of 1·75 cm. diameter and 5 cm. long, a great change takes place both in the force of the extra currents and the resistance in the variable period—the extra currents fall in value from 460 to 352, whilst the extra resistance is increased to 52 per cent. above that of the stable period; we have here a double and contrary effect, the reduction of the force of the extra currents and the increase in the resistance cannot be due to the magnetic nature of copper, but must be due to the induced or so-called "Foucault currents" circulating in the core; to prove this the core was replaced by another similar in every respect but cut longitudinally to its centre: the currents now ceased to circulate, and the copper core had not the slightest effect either on the extra currents or the variable resistance; this is shown in the table, where, for greater precaution, a core of insulated copper wires replaced the solid core. Evidently the induced current in the core was the cause of the extra resistance; work was done by the primary current, and a loss of energy at the expense of the electro-motive force of the extra currents, but in doing this work a resistance was produced which was no doubt caused by the currents circulating in the core. These currents required time, passing through the variable stage and thus producing from their electro-magnetic inertia an equivalent reaction and electro-magnetic inertia in the primary coil itself. That this inertia is due to the electro-magnetic character of the current, and not to an electric current considered apart, is proved by the fact (which I have verified) that, when we coil a wire into a coil of several superposed layers, its electro-magnetic reactions introduce a measurable resistance in the variable period, precisely similar though feebler, than that which would be produced by the reaction on the conductor of a magnetic body such as iron.

The effect of a solid iron core and a bundle of iron wires on the increase of the force of the extra currents is well known, but the table shows an interesting result as to their effects on the variable resistance; the solid iron core shows a very high force of extra currents produced by its magnetic reaction on the wires of the helix, the resistance in the variable period has increased 275 per cent., and its extra currents are extremely high, as we should expect; now, if the extra resistance is due to magnetic reaction alone, it should increase when we are enabled to increase this reaction, but if it is due in greater part to the electro-magnetic inertia of electric currents circulating in the bar, then, by preventing these currents from being formed (as we did in the case of copper), we should greatly reduce the extra resistance. This proved to be the case, for on replacing the solid iron core by a bundle of

fine iron wires the force of the extra currents rose from 2338 to 5360, or more than double the force of that produced by a solid bar, whilst the resistance in the variable period fell from 275 to but 69 per cent.

It is well known that a bundle of fine wires magnetises quicker than a solid bar, and this may have had its effect, although a not more important one than that of the suppression of the eddy currents, as the latter may be the cause of the former. The table shows that where we have suppressed these currents as far as possible, by introducing a core of insulated wires containing less iron than in the previous experiment, but fully insured against eddy currents, the induction was the highest and the resistance the lowest yet found for a helix containing an iron core; the experiment proves, to my mind, that the extra resistance found in the three last experiments is due both to the electro-magnetic inertia of the eddy currents and the inertia of the magnetic molecules of iron.

The experiments related in this paper have been most carefully made and verified, and, from the ease and certain action as well as the invariable results obtained by the method which I have described, they should be easy to repeat by others.

If we regard the whole of these researches we cannot fail to notice certain important laws which act in the greater portion of them. I have shown: 1st. That the contiguous portions of the same current react upon each other in the interior of its own portion of the conductor similar to their known exterior reactions on separate portions of the same conductor. 2nd. That the coefficient of mutual induction is less in iron than copper wires, but that their coefficient is the same when the conductor is in the form of a ribbon. 3rd. That the inductive capacity of different metals depends on their specific resistance, on their electro-magnetic capacity for circular magnetism, and on the geometrical form of their conductors. 4th. That the inductive capacity of a conductor of magnetic metal is dependent upon the formation of circular magnetism and not upon its internal magnetic permeability. 5th. That a magnetic, metal can be rendered equally free from circular magnetism as the non-magnetic metals. 6th. That we have experimental evidence of electro-magnetic inertia and the deleterious effects of eddy currents in the cores of electro-magnets.

In addition to the above effects, we have the discovery of a large increase in the ohmic resistance during the variable period, allowing us to demonstrate and measure the gradual rise of an electric current in its conductor.

In conclusion, I desire to express my warmest thanks to Lord Rayleigh, Mr. F. L. Pope, Professor Forbes, Dr. Hopkinson, Mr. W. H. Preece, Dr. Fleming, Mr. Fitzgerald, Professor Silvanus Thompson, and Professor Ayrton, for the important theoretical contributions they gave on the discussion of my first paper. Mr. W. H. Preece, Electrician to the Post Office, not only gave information of great practical value, but has kindly supplied me with the wires used in these experiments. The discussion proved the necessity of the researches which I have undertaken, and the importance of an experimental determination of the self-induction of an electric current in relation to the nature and form of its conductor.

A. SCHUSTER—ON THE DIURNAL PERIOD OF TERRESTRIAL MAGNETISM.

(*Phil. Mag., Vol.* 21, *No.* 131, *April*, 1886, *pp.* 349–59.)

The study of this question is of great interest, as the increase in amplitude of the diurnal variation of the horizontal component of magnetic force forms one of the most striking effects accompanying sun-spot activity.

If electric currents parallel to the earth's surface produce any disturbance, and if we find the distribution of magnetic potential on the surface of the earth from the horizontal component only, we should get by calculation a vertical component of different sign according as the cause is outside or inside the earth. A comparison with observed values will therefore at once settle this question.

We may leave out of account the variations of electrification on the earth's surface; for from electrostatic observations of Sir William Thomson it would appear that if charges such as described by him occurred over an area about 20 per cent. larger than Ireland, the displacement current would be equivalent to one ampère, while it would require a current of 4,000 ampères over the same surface to cause a deflection of one minute of arc in the declination.

On the assumptions made the northerly component of horizontal force ought to be a maximum and a minimum whenever the westerly component vanishes. At Greenwich the northerly component has a maximum at 7 o'clock in the evening, and a minimum at noon; while the westerly component vanishes a little after 7 o'clock, and between 12 and 1 in the afternoon. At Bombay the declination needle seems to pass its mean position on the average a little after 10 in the morning and about 10 in the evening. The horizontal force has its maximum a little after 11 in the morning, and the minimum at a quarter past 9 in the evening. Considering that, owing to the southerly position of Bombay, the type in the declination range differs considerably in our own latitude, the agreement is satisfactory, and so far tends to disprove the existence of vertical currents through the earth's surface. The observations taken at Lisbon and Hobarton show an equally good agreement, those at St. Helena and the Cape less so; but in these two latter places the observations taken at different months show a considerable difference of behaviour.

It is possible to obtain an idea as to the direction and intensity of the currents which may be the cause of the diurnal variation. If the equations arrived at are approximately correct, the northerly force ought to be a maximum in the morning, and a minimum in the afternoon, in the equatorial regions, where the term containing the latitude has a negative sign; while in the latitudes above 45° the minimum ought to take place in the morning. This is exactly what happens, with the exception that the change seems to take place in latitudes smaller than 45°. At Bombay the maximum of horizontal force takes place at 11 o'clock a.m.; at Greenwich the minimum takes place at a little after that time; at Lisbon (lat. 51°) the minimum lies, as at Greenwich, in the morning, but the range is considerably reduced.

Considerable importance is to be attached to the fact that the maxima

and minima of horizontal force as deduced from the equation agree in sign with the observed phenomena, for, as regards magnitude, all these variations might equally well be due to currents crossing the surface of the earth; but the *sign* of the northerly component would have to be reversed so that the minima and maxima would be inverted. This is another argument in favour of the supposition that no appreciable part of the diurnal variation is due to currents crossing the surface of the earth.

In the case of the vertical force also the results, as far as they go, give an emphatic answer in favour of the supposition that a great part, at any rate, of the disturbing currents lie outside the earth's surface.

On studying the direction and intensity of the currents at Greenwich and Bombay it is remarkable how very nearly at the same local hours the currents flow north and south, viz., at 4 in the afternoon and between 7 and 8 in the morning. It is curious, moreover, how very quickly the current turns through the meridian at Bombay: at 3 o'clock it flows at an angle of 15° from the east, and already at 5 it flows due west, and remains almost unaltered in direction till 5 o'clock in the morning. At Greenwich the currents turn much less sharply, but they always flow east when the currents at Bombay flow west. Along the meridian—on which the local time is 4—the currents flow from the equator towards the north, they turn round in our latitude towards east and west, join on either side again to go south—where the local time is 7.30 in the morning—and come back along the equator.

A. P. LAURIE—ON MEASUREMENTS OF THE E.M.F. OF A CONSTANT VOLTAIC CELL WITH MOVING PLATES.

(*Phil. Mag., Vol.* 21, *No.* 132, *May,* 1886, *pp.* 409–15.)

The object in view was to determine the E.M.F. corresponding to a definite set of chemical reactions, and to do this satisfactorily it was desirable that the products of the reaction should be sufficiently large to admit of quantitative estimation; hence a considerable current had to be drawn off from the cell. But a large current means a fall in the E.M.F. of the cell under test, which is usually considered as due to "polarisation," "transition resistance," &c., but which, on fuller consideration, is more likely caused in great part, or perhaps entirely, by alterations in the layers of liquid next the plate; and this fall of E.M.F. may be largely a question of the rate of diffusion of the salts dissolved in the liquid used in the cell.

In order to assist the diffusion, and thereby check the fall of E.M.F., the author made use of a battery consisting of a shallow glass jar lined with platinum foil as one electrode, while the other electrode was a plate of cadmium fixed to a pulley placed horizontally above the jar, by means of which it could be made to revolve at a rate of two or three revolutions per second in the liquid, containing about five per cent. of cadmium iodide and 0·0032 gram. of free iodide per cubic centimètre of solution.

After setting up the cell, its E.M.F. was measured by comparison with a

Latimer Clark cell by means of an electrometer, and found to be 1·076 volt. The plate of cadmium being then started moving, the cell was connected up to a galvanometer, and the current measured as 0·1054 ampère; the total resistance of the circuit was found by interpolating known resistances in the circuit to be 10·12 ohms; and the calculated E.M.F. was therefore found to be 1·084 volt as a mean value. After allowing the current to run through the galvanometer for nearly two hours, the deflection measured a current of 0·1068 ampère; and the calculated E.M.F. with a mean circuit resistance of 10 ohms was 1·067 volt, while from the electrometer it was found to be 1·072 volt on comparison with the Latimer Clark cell. The method, therefore, is seen to be capable of giving accurate results if greater care in details is taken.

A striking experiment is to suddenly stop the movement of the plate while the cell is connected to the galvanometer. The needle at once begins to move, falling in less than a minute to about a quarter of its original deflection. On now allowing the plate to start off again, the needle rushes up to its old position.

BALFOUR STEWART—ON THE CAUSE OF THE SOLAR DIURNAL VARIATIONS OF TERRESTRIAL MAGNETISM.

(*Phil. Mag., Vol.* 21, *No.* 132, *May*, 1886, *pp.* 435–45.)

The hypotheses which have generally been advanced are three—first, that of the direct magnetic action of the sun upon the earth; second, that of Faraday, viz., the heating effect of the sun on the earth's atmosphere; and, third, earth currents. There are, however, serious objections to all three, and we are led to look for the cause of the diurnal variation of the terrestrial magnetism in the existence of a set of electric currents in the upper regions of the earth's atmosphere. There are two objections which may be raised, viz., that at elevated regions in the atmosphere the rarefied air is not a good conductor, and that it is difficult to see why such currents should be one and a half times more powerful at times of maximum than at times of minimum sun-spot frequency. As regards the former, we have the *fact* that currents do exist in the upper regions of the air, as is shown by the occurrence of auroræ boreales; while, as regards the second, the greater activity of the sun at periods of maximum sun-spot frequency will tend to heat the upper regions of the atmosphere and thereby render them better conductors. The author then goes on to consider Dr. Schuster's theory, of which an abstract is given above, and with which he fully agrees.

G. B. PRESCOTT—ELECTRICAL PROPERTIES OF GERMAN SILVER.

(*The Electrician and Electrical Engineer, Vol.* 5, *No.* 52, *April*, 1886, *pp.* 126–28.)

Notwithstanding the great use made of German silver wire for resistance coils, &c., there is no uniformity amongst manufacturers in the proportions of copper, nickel, and zinc used to make the alloy; and in all statements by

various authorities as to its specific resistance no mention is made of its percentage composition, but only some vague expression such as "the alloy usually used for resistance coils." The following tables may, therefore, be of some use. In the first one are given the results of tests of samples of German silver wire, bought in the open market. Matthiessen's temperature correction for German silver is 0·024 per cent. per degree Fahrenheit, but as this figure is obviously too great for wire of higher specific resistance, the results have not been corrected to a standard temperature. The unit of comparison adopted is the weight in pounds of one mile of wire having one ohm resistance. This unit, known as the weight per mile-ohm, if divided by the weight per mile, in pounds, of any other similar wire, gives as a quotient the resistance per mile of that wire. The specific resistance of an alloy is therefore proportional to its weight per mile-ohm. For comparison it may be stated that high conductivity iron wire has a mile-ohm under 4,800 lbs. at 68° F., and that the weight per mile-ohm of pure copper at 60° F. is 871 lbs.

Table I.—Commercial German Silver Wire.

Wire.		Diameter. Mils.	Weight per foot. Grains.	Resistance per foot. Ohms.	Temp. Fahrenheit.	Mile Ohm. Lbs.
Maker.	Lot.					
Matthiessen B.A. Report ...		0·142	1·000	2·68	60°	10,672
Elliott Bros.		1·000	0·02023	150·00	60°	12,088
American Electric Works ...	No. 1	8·75	1·531	2·3789	81°	14,504
" " " ...	"	6·65	0·8874	4·197	81°	14,495
" " " ...	"	8·75	1·561	2·3898	86°	14,857
" " " ...	"	6·65	0·8928	4·2005	86°	14,896
" " " ...	No. 2	8·5	1·457	2·6137	78°	15,165
" " " ...	"	6·4	0·8241	4·6289	78°	15,192
Coe Brass Co.		44·5	41·251	1·0035	83°	16,590
" "		20·5	8·708	4·6857	83°	16,353
Holmes, Booth, & Haydens		6·2	0·9332	5·2174	86°	16,514
" " "		8·1	1·363	3·2861	86°	17,834

Table II.—German Silver Alloys. Experiments by E. Weston. Temperature about 75° F.

Alloy No.	Composition.			Weight per Mile-Ohm. Lbs.	Per-centage of Nickel.	Remarks.
	Copper.	Nickel.	Zinc.			
64	100	20	50	11,572	12	
83	100	30	50	14,599	17	
55	100	33	50	15,325	18	Remelted.
62	100	33	50	15,448	18	Remelted.
60	100	33	50	15,626	18	Redrawn.
63	100	30	30	15,599	19	
65	100	40	50	18,054	21	
101	100	50	50	18,172 (?)	25	New lot nickel.
79	100	50	50	19,009	25	
92	100	50	50	19,077	25	Lost weight.
90	100	50	50	19,594	25	
91	100	50	50	19,670	25	
77	100	50	50	20,354	25	
78	100	50	50	21,402	25	
—	100	78·74	52·75	24,485	34	

If properly annealed, it does not appear that drawing German silver into wire alters its electrical properties, but during the melting process more or less of the zinc is oxidised, and the proportions of the finished alloy therefore differ somewhat from those of the original mixture. Mr. Weston has also investigated the properties of the new alloy called platinoid, which is German silver containing a small proportion of tungsten, and he finds that the addition of the tungsten has not the slightest effect on the electrical properties of German silver even when present to the extent of five per cent. On the other hand, the resistance varies almost directly with the quantity of nickel, and the effect of changes of temperature on the resistance of the alloy varies inversely as the quantity of nickel; in other words, the greater the percentage of nickel, the smaller the temperature correction. The effect of the zinc is to make the alloy more ductile, and its presence is useful for mechanical reasons.

LEDEBOER—DETERMINATION OF THE COEFFICIENT OF SELF-INDUCTION.

(*Comptes Rendus, Vol.* 102, *No.* 11, *March* 15, 1886, *pp.* 606–608.)

A Deprez-D'Arsonval galvanometer, the resistance of which is so arranged that the movement of the needles is just dead beat, is used in Maxwell's method as it has been applied by Lord Rayleigh. The only difference is the

introduction into the formula for a balistic galvanometer of the factor ϵ, the base of the natural logarithms. For general purposes the formula is

$$L = r \cdot \frac{T}{\pi} \cdot \frac{\delta}{a} \cdot \epsilon;$$

but where the resistance of the bobbin whose coefficient of self-induction has to be determined is very small, the added resistance (r) is so small as to be difficult of accurate measurement, even on Thomson's bridge. In such cases it is preferable to use the formula

$$L = \frac{T}{\pi} \cdot \frac{i}{a} \cdot \epsilon \cdot \frac{\delta}{1} \left\{ (R^1 + l^1 + g) \frac{R}{R^1} + g \right\},$$

in which $\frac{i}{a}$ is the constant of the galvanometer, the total resistance of which is g; R, R^1, l, l^1, are the resistances in the four arms of the bridge, R being that of the bobbin, whose coefficient of self-induction is L; with $/R^1 = l/l^1$, the galvonometer being connected up between R and R^1 on one side, and between l and l^1 on the other.

M. DEPREZ—AN INSTRUMENT BY MEANS OF WHICH AN INVARIABLE QUANTITY OF ELECTRICITY CAN BE PRODUCED AT WILL.

(*Comptes Rendus, Vol.* 102, *No.* 12, *March* 22, 1886, *pp.* 64–666.)

This instrument is designed to reproduce at any time and under any circumstances exactly one coulomb of electricity, and is, in fact, a hermetically sealed voltameter. It consists of a U tube, the two legs of which are sealed in the blow-pipe flame, and end in bulbs the volume of which is considerably greater than that of the tube. One of these bulbs, as well as the leg in communication with it, is completely filled with water acidulated with phosphoric acid; the other leg contains only a small quantity of this liquid in its lowest part, but for the greater part of its length it is filled with air at a fixed pressure, as is the bulb on the top of it. The leg filled with liquid has four platinum wires fuzed into it, two opposite each other at the top of the bulb, and two others in the cylindrical part of the tube a little below the bottom of the bulb. On passing a current through these two latter wires electrolysis takes place, and the gases evolved collect in the bulb, forcing the liquid to rise in the other leg of the U tube. This latter is graduated, and consequently the exact quantity of electricity used for the decomposition is readily measured by the rise of the column of liquid. The instrument, being hermetically sealed, is independent of variations of pressure and temperature, and is more especially of service for standardising other instruments. The evolved gases can be made to recombine by passing a spark discharge between the second pair of platinum wires in the upper part of the bulb.

G. CHAPERON—THERMO-ELECTRIC PROPERTIES OF SOME BODIES.

(*Comptes Rendus, Vol.* 102, *No.* 15, *April* 12, *pp.* 60–863.)

The method employed is applicable to very small pieces of the material under examination. The fragment is held in a spring clamp, part of which consists of a thin silver tube traversed by a current of water, and is pressed against an iron crucible filled with a molten alloy. From the crucible a silver wire, sufficiently long to remain cold at its further extremity, goes to the measuring instrument, which is also connected with the silver tube. Owing to the enormous resistance of the couple, the only instrument which can be used is a Lippmann electrometer, which shows that the E.M.F. of the couple is equal to that given by a wire potentiometer. It would appear that a great number of bodies are capable of forming thermo-electric couples: thus iodide of silver has a positive valuè of 0·115 volt, sulphide of tin 0·052 volt, while sulphide of silver has a negative value of 0·091 volt. This last substance is peculiar in that it is reduced to the metallic state when it is traversed by a flow of heat between two conducting surfaces.

F. VAN RYSSELBERGHE—TELEPHONY OVER LONG DISTANCES.

(*L'Electricien, Vol.* 10, *No.* 161, *May* 15, 1886, *pp.* 307–13.)

The paper is a *resumé* of a great number of experiments carried out in America over long lines with the author's apparatus for simultaneous communication by telegraph and by telephone on the same wire.

The first experiments were made, during the day, when the wires were crowded, between Grafton and Parkersburg, a distance of 104 miles. Some of the wires on this line were iron of No. 9 gauge, the others copper No. 12, having a resistance of 6 ohms per mile. The results were most satisfactory. The Edison quadruplex instruments were unaffected, and conversations were carried on over the copper wires with a remarkable clearness, which was, however, wanting when the iron wires were used, though here also there was no difficulty in hearing what was said.

Having demonstrated the practicability of the method, further experiments were made on the wires from New York to Chicago, and from Baltimore to Chicago: on the former there are iron wires No. 8 gauge, and copper wires No. 12 and No. 14, of 6 and 8 ohms per mile respectively; while on the latter there are only iron wires. Conversation was possible between River (Ohio) and Fostoria (Indiana), 229 miles apart, over a No. 8 iron wire. Some words could be distinguished and the call was clearly heard between Grafton and Fostoria, 328 miles apart; but nothing at all between Baltimore and Fostoria, 620 miles apart. The impossibility of conversing over this length of iron wire is not due to the feebleness of the sounds transmitted, but they are confused and muffled, so that the articulation is lost.

This is not the case with copper wires, as was proved by conversation being carried on with ease between Fostoria and Albany (585 miles) over a

No. 12 copper wire. The outgoing wire had a resistance of 3,660 ohms, and the return wire a resistance of 3,347 ohms; the electrostatic capacity was 3·3 microfarads, and the insulation resistance 296 megohms per mile. A similar experiment made over the same distance on a No. 14 copper wire was not so successful.

As it appeared from the above experiments that the distance over which conversation was possible on a copper wire was only a question of the size of the wire, arrangements were made to work over a *compound* wire consisting of a No. 11 steel core covered with copper to No. 4. The length of the metallic circuit (outgoing wire and return) between Chicago and New York was 2,020 miles, its resistance 1·7 ohm per mile, and the electrostatic capacity for the looped line was 23·4 microfarads. At Chicago there were six miles of underground cable, and about a mile of cable under the Hudson. The result was marvellous. Every word was most clear and distinct, and the voice of the speaker could be recognised. It was possible to understand everything even when the telephone was held some inch or inch and a half from the ear.

C. HEIM—CONDUCTIVITY OF SUPERSATURATED SOLUTIONS.

(*Annalen der Physik und Chemie, Vol.* 27, *Pt.* 4, *No.* 4, 1886, *pp.* 643–56.)

The method of procedure was to warm the solutions, which contained varying proportions of dissolved salt, to a temperature at which the amount of salt in the solutions did not suffice to saturate them; they were then allowed to cool down gradually to below the point of saturation, successive measurements of the resistance being made at small intervals of time. The solutions were contained in a U tube provided with platinum plate electrodes into which were screwed stout platinum wires. This tube was placed in a double vessel, the outside lining of which could be filled with water or with a refrigerating mixture. In order to avoid all polarisation, the current used was an alternating one produced by an induction coil, a telephone being used instead of a galvanometer for judging when a balance had been reached.

From the experiments with zinc sulphate, sodium sulphate, magnesium sulphate, sodium carbonate, and calcium chloride, it would appear that there is no sudden change in conductivity as the solution passes into the supersaturated condition, and the curves plotted from the observations all follow a perfectly regular course. The values of the conductivity of supersaturated solutions may be deduced from Kohlrausch's formula

$$K_t = K_0 (1 + \alpha t + \beta t^2),$$

where the coefficients have the same values as in the case of non-saturated solutions. The observations were frequently continued quite up to the point of crystallisation, when the resistance sometimes increased to three times what it was when the body was still liquid.

W. von ULJANIN—MEASUREMENTS OF E.M.F.

(*Annalen der Physik und Chemie, Vol. 27, Pt. 4, No. 4*, 1886, *pp.* 657-65.)

At the present day the use of the electrometer is becoming more and more frequent for the determination of E.M.F.; but there are still many occasions where it is more convenient to use a galvanometric method. The author has therefore made a long series of experiments in which he has compared the electrometric determination of the E.M.F. with that obtained by the Poggendorf compensation method as modified by Du Bois-Reymond, and by H. S. Carhart. From the experiments on Daniell and Leclanché cells, it would appear that very accurate results can be obtained by the Du Bois-Reymond method, in which there are two circuits, having a graduated wire common to both. The one circuit contains the experimental cell and a galvanometer with a resistance, and the other the compensating cell and also resistances; one end of the former circuit is then shifted to various points on the graduated wire until no current passes through the galvanometer. This method is very widely known; that of Carhart is somewhat different. There are two circuits, having one part common to both, as before, this common part being a box of resistances. The one circuit contains the experimental cell and a galvanometer, the other the compensating cell and a silver voltameter. There is is no shifting contact, but the plate in the voltameter is raised and lowered for about ten minutes, so that there is never any current through the galvanometer; the E.M.F. of the experimental cell is then equal to the product of the resistance in the box into the current in the voltameter circuit, as determined by the weight of silver deposited This method does not give results as concordant with the electrometer method as does the Du Bois-Reymond compensation method. The reason for this is that some little time must elapse before the plates in the voltameter can be adjusted, and during this adjustment too great a current is passing, and consequently the quantity of silver deposited, from which the mean current is calculated, is also too large; further, as the current is circulating for some ten minutes, the value of the resistance in circuit will alter. The author therefore gives the preference to Du Bois-Reymond's method.

R. COLLEY—DETERMINATION OF v.

(*Annalen der Physik und Chemie, Vol.* 28, *Pt.* 1, *No.* 5, 1886, *pp.* 1–21.)

This is a description of a particular application of a method of observation of electrical oscillations, previously described by the author in the *Annalen* (vol. xxvi., p. 432, 1885), to the determination of the constant v—that is, the ratio of the electrostatic to the electro-magnetic system of units. The method is particularly applicable, as it is independent of any determination in absolute measure of current, E.M.F., or resistance. From the previous considerations of the method—where r was the resistance of the circuit, p its coefficient of self-induction, c the capacity of the condenser, and t the time of one oscillation—it was found that the value r^2 was negligible in comparison with $\frac{4\,p}{c}$; hence it was found that

$$t = \pi \sqrt{p\,c}.$$

Both quantities under the radical sign are of course expressed in units of the same system, *e.g.*, the electro-magnetic; if, then, the capacity of the condenser is measured also in electrostatic units (say C), we have the ratio between c and C, $c = \frac{C}{v^2}$; and by substitution

$$v = \frac{\pi}{t} \sqrt{p\, C}.$$

The coefficient of self-induction p in electro-magnetic units, and the capacity C in electrostatic units, are both of linear dimensions, and the formula therefore shows at once that v is a velocity. From the formula it also appears that in order to determine v it was only necessary to know the coefficient of self-induction of the coil in electro-magnetic units, and the capacity of the condenser in electrostatic units, and then, having joined both up in one circuit, to measure the period of oscillation in that circuit.

A standard coil was constructed with the utmost care, and its coefficient of self-induction calculated from formulæ of Maxwell and Stefan, knowing the mean radius, the width and depth of the winding. With this standard coil others were then compared by means of the bridge as described by Maxwell. The values were probably correct within $\frac{1}{100}$.

A standard condenser was also constructed of silvered glass plates, the dielectric being air. From the geometric dimensions of this condenser, its capacity could be calculated, and it then served as a standard for the measurement of various tinfoil condensers by the deflection method.

All experiments were made with minute care, and corrections were introduced where necessary. As his final value the author gives $v = 3{\cdot}015 \times 10^{10} \frac{\text{cm.}}{\text{sec.}}$; he also adds a table of previously found values, which it may be convenient to reproduce for reference :—

Weber and Kohlrausch	$3{\cdot}107 \times 10^{10} \frac{\text{cm.}}{\text{sec.}}$
W. Thomson	2·82 „ „
Maxwell	2·88 „ „
Ayrton and Perry	2·98 „ „
Hockin	2·988 „ „
Stoletow	2·98 to 3·00 „ „
J. Thomson	2·936 „ „
Exner	2·92 „ „
Rowland	3·045 „ „
Klemencic	3·019 „ „

The latest determinations of the velocity of light are :—

Cornu, 1874	$3{\cdot}004 \times 10^{10} \frac{\text{cm.}}{\text{sec.}}$
Michelson, 1880	2·9994 „ „
Young and Forbes, 1882	3·0138 „ „

H. JAHN—THE RELATION OF CHEMICAL ENERGY AND CURRENT ENERGY IN GALVANIC CELLS.

(*Annalen der Physik und Chemie, Vol.* 28, *Pt.* 1, *No.* 5, 1886, *pp.* 21–43.)

The relation of the energy produced in the external circuit of a cell with the loss of potential chemical energy in the cell itself has been the subject of investigations by many physicists. Lately v. Helmholtz has investigated the question theoretically, and has arrived at the expression

$$Q = a\,\theta\,\frac{dp}{d\theta}\,I,$$

where a is Joule's equivalent of heat, θ the absolute temperature, and $\frac{dp}{d\theta}$ the temperature coefficient of the E.M.F. of the particular cell; while Q is the quantity of heat which must be given to or drawn from a non-polarisable cell so that its temperature may remain constant while the current I flows through it.

It appears from this formula that Q can only become nil—*i.e.*, that the whole potential chemical energy is converted into current energy—when

$$\frac{dp}{d\theta} = 0 \text{ or } p = \text{constant};$$

when, therefore, the E.M.F. does not alter with the temperature. If the E.M.F. increases for a rise in temperature, then heat must be given to the cell in order that the temperature may remain constant; if, on the contrary, the E.M.F. falls for an increase of temperature, heat must be drawn from the cell in order that its temperature may remain constant.

The author has undertaken a series of experiments with various cells in order to test this theory. The heat developed in the cell itself was measured in the calorimeter in which it stood, while the heat produced in the outer circuit was calculated from accurate measurements of the current, E.M.F., and resistance.

A glance at the following table, in which the author has summarised the experimental results (fully described in the original), will show very clearly that his experiments are entirely in support of the theory of v. Helmholtz, not only qualitatively, but also quantitatively:—

Kind of Cell.	E.M.F. Volts.	Current Heat. Calories.	Chemical Heat. Calories.	Temp. Coeff. Volt.	Secondary Heat. Calories.	
					Found.	Calcultd.
$Cu . Cu SO_4 + 100 H_2O \parallel Zn . Zn SO_4 + 100 H_2O$	1·0962	50·526	50·110	+0·000034	−0·416	−0·428
$Cu . Cu(C_2H_3O_2)_2 aq \parallel Pb . Pb(C_2H_3O_2)_2 + 100 H_2O$	0·47643	21·96	16·523	+0·000385	−5·437	−4·844
$Ag . Ag Cl \parallel Zn . Zn Cl_2 + 100 H_2O$	1·0306	47·506	52·17	−0·000409	+4·66	+5·148
$Ag . Ag Cl \parallel Zn . Zn Cl_2 + 50 H_2O$	1·0171	46·896	49·082	−0·00021	+2·186	+2·644
$Ag . Ag Cl \parallel Zn . Zn Cl_2 + 25 H_2O$	0·9740	44·908	47·147	−0·000202	+2·239	+2·54
$Ag . Ag Br \parallel Zn . Zn Br_2 + 25 H_2O$	0·84095	33·772	39·936	−0·000106	+1·164	+1·334

B. C. DAMIEN—EXPERIMENTAL RESEARCHES ON THE E.M.F. OF CELLS WITH ONE LIQUID, ONE SOLUTION OF A SALT.

(*Beiblätter, Vol.* 10, *No.* 3, 1886, *pp.* 185–87; *Ann. de Chim. et de Phys.* (6), 5, *pp.* 289–313.)

The measurements consisted in the comparison of the experimental cell, by means of a Mascart electrometer, with a standard Latimer Clark cell, the needle of the electrometer being kept at a constant potential by 100 cells, with zinc and copper in a solution of magnesium sulphate.

The E.M.F. of cells with sulphates, nitrates, and carbonates decreases in time; that of cells with chlorides rises to a maximum and then falls off; cells with sulphate of magnesium and chloride of calcium reach a constant value after about 12 days. When solutions of carbonates are used, the E.M.F. falls very rapidly.

A cell consisting of zinc and copper in solution of magnesium sulphate is very constant in spite of changes in temperature and in degree of concentration. A battery of 100 cells, after being short-circuited for one minute, at once regained its value on the circuit being opened.

Experiments were also made with cells containing plates of platinum and amalgamated zinc in sulphuric acid of various degrees of concentration—from 92 per cent. to 30 per cent., and down to 0 per cent.: the values were 1·264, 1·345 (maximum at 30 per cent.), and 1·083. With solutions of caustic soda from 23·5 per cent. to 2 per cent., and down to 0 per cent., the force diminishes from 1·342 to 1·287 and 1·083; with caustic potash from 25 per cent. to 0·2 per cent. and 0 per cent., 1·390 to 1·282 and 1·083; so that very small quantities of potash added to the water cause a considerable increase of E.M.F., which is only slightly augmented by further considerable additions of the salt

With the chloride of silver cell of Warren de la Rue (E.M.F. = 1·03), within the range of temperature of the laboratory, the force remains very constant to 60°, but on cooling it drops about one-half to one-third, owing to the solution of the chloride of silver and the deposit of some silver on the zinc plate.

The amalgamation of the zinc generally increases the E.M.F.; but the falling off is in time greater with amalgamated than with unamalgamated zinc. Thus in the case of a cell consisting of copper, zinc, and spring water, after 2 hours and 340 hours the values found were—Unamalgamated, 0·811 and 0·625; amalgamated, 0·928 and 0·273.

E. CORMINAS—SODIUM-CARBON CELL.

(*Beiblätter, Vol.* 10, *No.* 3, 1886, *pp.* 187–88; *Centralblatt für Electrotechnik*, 7, *p.* 491, 1885.)

The carbon or platinum electrode is in a porcelain pot; a rectangular block of soda, in which is imbedded a copper wire, is pressed against the porcelain pot by elastic bands. A siphon with ends drawn out to capillary tubes lets

drop some of the liquid from the porcelain pot on to the soda. The E.M.F. in volts for various exciting liquids is given below :—

	Solution.	Parts by Measure.	Volts.
1.	Caustic soda		3·0
2.	Hydrochloric acid (conc.)		3·2
3.	Sulphuric acid / Water	30 / 100	3·3
4.	Sodium nitrate / Sulphuric acid	30 / 10	3·3
5.	Potassium chlorate (conc.)		3·5
6.	Potassium chlorate (conc.) / Sulphuric acid	13 / 6	3·6
7.	Potassium chlorate (conc.) / Hydrochloric acid (conc.)	50 / 50	3·6
8.	Potassium bichromate / Sulphuric acid	100 / 30	3·8
9.	Nitric acid (conc.)		3·8
10.	Potassium permanganate (conc.)		4·0
11.	Potassium permanganate (conc.) / Sulphuric acid	100 / 30	4·5
12.	Potassium permanganate (conc.) / Sulphuric acid	55 / 50	4·5

Dr. A. von WALTENHOFEN—SOME PRACTICAL FORMULÆ FOR THE CALCULATION OF ELECTRO-MAGNETS.

(*Centralblatt für Elektrotechnik, Vol.* 8, *No.* 8, 1886, *pp.* 155–59, *and No.* 9, *pp.* 175–80.)

Several expressions have been given for calculating the magnetic moment of an electro-magnet from the dimensions, the current, and the number of turns of wire, but all contain constants the values of which have not been determined. The general formula given by the author is

$$y = k\sqrt{l^3 \cdot d} \times n\,i \qquad \ldots \quad \ldots \quad \ldots \quad (1)$$

where y is the magnetic moment, l is the length of the iron core, d its diameter, and $n\,i$ the product of the number of convolutions of wire into the current; k is a constant to determine the value of which the author has been making experiments on large magnet bars such as are used in dynamos, and he has found $k = 0{\cdot}315$. This gives us the magnetic moment; but we want also to know the degree of saturation to which this magnetic moment corresponds, and for this we must find the maximum moment. From various determinations it appears that the magnetic maximum—*i.e.*, the magnetisation which can be attained in a magnetic field of infinitely great intensity—is 212·5 C.G.S. units per grain of iron. Hence the magnetic maximum of an iron cylinder of length l and diameter d in centimètres would be given by the expression

$$y^1 = 212{\cdot}5 \times \frac{\pi}{4}\, l\, d^2 \times 7{\cdot}78 = 1298\, l\, d^2 \qquad \ldots \quad \ldots \quad (2)$$

if we take the specific gravity of iron as 7·78.

The percentage saturation is then found from

$$p = 100 \frac{y}{y^1} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

A convenient formula for calculating the percentage saturation is found by division of the first two equations and multiplication by 100. We have

$$p = 0{\cdot}0104 \sqrt{\frac{l}{d^3}} \times n\,i \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

If a certain number of coils are wound on a given length of the core, *e.g.*, m windings per centimètre, then, since $n = m\,l$,

$$p = 0{\cdot}0104 \sqrt{\frac{l^3}{d^3}} \times m\,i \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

By conversion of this formula we obtain

$$l = 21 \left(\frac{p}{m\,i}\right)^{\frac{2}{3}} \times d \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

which enables us to reckon the length to be given to any core in order to obtain a given degree of saturation, the winding and current being known.

One or two practical examples may serve to render the use of these formulæ more clear.

An iron core 7 cm. thick has 14 turns of wire per cm.: what must be its length to give 30 per cent. saturation with 15 ampères? Taking formula 6, we have

$$l = 21 \left(\frac{30}{14 \times 15}\right)^{\frac{2}{3}} \times 7 = 40 \text{ cm. approximately.}$$

An electro-magnet of a Schuckert dynamo was 7 cm. thick and 13·5 cm. long, with 192 turns of wire: with a current of 10 ampères what was its magnetic moment and saturation?

$$\text{I. From (1) } y = 0{\cdot}135 \sqrt{13{\cdot}5^3 \times 7} \times 192 \times 10 = 34015.$$

$$\text{II. From (4) } p = 0{\cdot}0104 \sqrt{\frac{13{\cdot}5}{7^3}} \times 192 \times 10 = 3{\cdot}96 \text{ per cent.}$$

The effect of pole-pieces has also been investigated, and the author has sought to find a formula which should apply to this case also. From his various experiments he concludes that the following expression may serve as an approximation :—

$$M^1 = M \left(\frac{P + p}{P}\right)^{\frac{5}{3}} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

where M is the magnetic moment without pole-piece to be calculated from formula (1), P is the weight of the cylindrical bar, and p that of the pole-piece.

A well-known formula for electro-magnets is that given by Müller—

$$y = B\,d^2 \tan.^{-1} \frac{n\,i}{A\,d^{\frac{3}{2}}} \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

The values of the coefficients have been calculated by the author, and he finds

$$A = \frac{6112}{\sqrt{l}}; \quad B = 14{\cdot}4\,l;$$

hence the equation (8) becomes

$$y = 14{\cdot}4\,l\,d^2 \tan.^{-1} \frac{\sqrt{l}}{6112\,d^{\frac{3}{2}}} \times n\,i \quad \ldots \quad \ldots \quad (9)$$

M. BAUMGARDT—MEASUREMENT OF SELF-INDUCTION.

(*Centralblatt für Elektrotechnik*, *Vol.* 8, *No.* 11, 1886, *pp.* 215–17.)

The coil the self-induction of which is to be measured, and a Wiedemann's galvanometer with sliding coils, are joined up in parallel in the circuit of a battery—the experimental coil being placed between the two coils of the galvanometer; each branch circuit also contains resistances. The circuits are so joined that the action of the experimental coil and of the galvanometer coils on each other is opposed. By shifting the galvanometer coils all induction of the experimental coil on them is eliminated. By suitable choice of the resistances in the two branches the needle of the galvanometer is brought back to its original position. If, then, r_1 is the resistance in the galvanometer branch, r_2 in the coil branch, a the deflection when the current in the coil is reversed, b when the main circuit is interrupted, m the coefficient of self-induction of the galvanometer, l that of the coil, t the time of oscillation of the magnet, R the damping constant, then

$$l = 2\, r_2 \;.\; \frac{t}{\pi} \sqrt{\mathrm{R}} \;.\; \frac{b}{a} + m \frac{r_2}{r_1}.$$

STRECKER—PHOTOMETRY.

(*Elektrotechnische Zeitschrift*, *Vol.* 7, *No.* 4, *April*, 1886, *pp.* 146–59.)

The author gives a general review of the whole question of photometric measurements, and of the various kinds of photometers invented at various times. Since the lights which we have to measure are only perceived by the eye, it is to the eye that we must appeal for the final test of the equality of lights; and it is not desirable to make use of some other effect of light than that produced on the retina, such, for instance, as the action of light on selenium or on some chemical compounds. The eye being the ultimate test, it remains to be seen which is the best instrument to assist the eye in its decision, and this appears undoubtedly to be the form of photometer due to Bunsen, in which a screen of paper with a grease spot in the centre serves to show when the illuminating powers of two sources of light have equal effect on it. In some cases it is preferable to use, in place of the single sheet of paper with the grease spot, three thicknesses of paper, the middle one having a geometric figure of some kind, generally a star, cut out of it. With regard to the standard with which the light is to be compared, the standard candle cannot be recommended, except in the hands of very skilled and competent observers. The normal unit lamp proposed by v. Hefner-Alteneck, in which amyl acetate is burned, can be depended upon with far greater certainty to produce always the same light for the same height of flame; the standard candles, on the average, being about 3 per cent. out. It is desirable, however, when measuring lights of great intensity, to have an intermediate standard, which is first compared with the standard unit, and then in turn used for

comparison with the experimental light. For such a purpose a petroleum lamp of good construction, or a gas flame burning under constant pressure, may be used.

A ready method of comparing a batch of glow lamps is the following:—In the circuit of a battery are introduced two branch circuits in parallel: the one contains a standard glow lamp of the same type as those to be tested, a resistance, and one coil of a differential galvanometer; the other branch circuit contains the lamp to be tested, a resistance, and the second coil of the differential galvanometer. From one terminal of the standard lamp to one terminal of the experimental lamp is a circuit of very high known resistance containing a galvanometer; this latter serves to show the difference of potential between the two lamps, while the differential galvanometer shows the difference in current, and the photometer the difference in light, and the whole of the measurements can conveniently be taken at once.

O. FRÖLICH—LAW OF THE ELECTRO-MAGNET.

(*Elektrotechnische Zeitschrift, Vol. 7, No. 4, April, 1886, pp. 163–65.*)

It has been stated by Professor Thompson that the author's formula for the magnetism of a dynamo machine and Lamont's formula are the same. This is not, however, the case. Let m be the actual magnetism, M its maximum, χ the product ampère-turns, k a coefficient expressing the first increase of the magnetism; then Lamont's formula is

$$\frac{d\,m}{d\,\chi} = k\,(\mathrm{M} - m), \text{ or } m = \mathrm{M}\ (1 - e^{-k\,\chi});$$

and Frölich's

$$m = \mathrm{M}\,\frac{k\,\chi}{1 + k\,\chi}.$$

If these formulæ are expanded in terms of χ, they become respectively

$$m = \mathrm{M}\,k\,\chi\left(1 - \frac{k\,\chi}{2} + \frac{k^2\,\chi^2}{6} - \&\text{c.}\right);$$

$$m = \mathrm{M}\,k\,\chi\,(1 - k\,\chi + k^2\,\chi^2 - \&\text{c.}).$$

If, for equal values of M and k, the curves corresponding to these two equations are plotted, they do not coincide, but differ considerably after a little. Also, for the value $k\,\chi = \frac{3}{5}$, they are not equal, as Professor Thompson supposes, but

$$1 - e^{-k\,\chi} = 0{\cdot}451; \text{ while } \frac{k\,\chi}{1 + k\,\chi} = 0{\cdot}375.$$

Again, the formula of Lamont holds good for all values of the current; while for $k\,\chi > 1$, Frölich's formula, when developed, becomes

$$m = \mathrm{M}\,\left(1 - \frac{1}{k\,\chi} + \frac{1}{k^2\,\chi^2} - \&\text{c.}\right),$$

which is not at all like Lamont's.

As to which formula is the more correct, some experiments have shown the degree of error in the values of m calculated from the formulæ and those

observed. The error is for Lamont's first formula as given above 2·02 per cent., but for a second formula, viz., $m = A - B\epsilon^{-kX}$, only 0·86 per cent., which is less than 0·95 per cent., the error from Frölich's formula.

O. FRÖLICH—ELECTRIC METERS.

(*Elektrotechnische Zeitschrift, Vol.* 7, *No.* 5, *May,* 1886, *pp.* 195–97.)

The apparatus described is one for giving a continuous record of the strength of a current, as, for instance, in the charging and discharging of accumulator cells. A paper slip driven by clockwork is drawn over a smoky lamp flame, which deposits on it a layer of soot; it then passes under a metal comb, which draws on it parallel lines. A long, light pointer attached to the current measurer then draws a wavy line on the slip as it is continuously unrolled. The chief point of interest, however, is the new method of damping introduced. It was necessary that the instrument should be dead beat, so as to obviate the tracing of a complicated curve. The damping is effected by attaching to the spindle an annular ring containing water; the ring is completely filled with water and then soldered up; the friction of the liquid inside the ring then damps its oscillations in the most effectual manner.

HANNS v. JÜPTNER—UNIVERSAL-ELECTRICITY METER.

(*Zeitschrift für Elektrotechnik, Vol.* 4, *Pt.* 4, *April,* 1886, *pp.* 171–75.)

The instrument is an improved form of Helmholtz's double-ring tangent galvanometer, very solidly built. The chief advantages seem to be that each ring carries a small table on which are connection blocks communicating with each coil of wire, so that by means of plugs any one or more coils may be readily coupled up as desired. There is also a plug commutator fixed to the pedestal, by means of which a standard resistance contained in the foot may be introduced, and the direction of the current in the two rings can be altered. The author gives formulæ for the measurement of E.M.F. by this instrument.

MAX DÉRI—ALTERNATE CURRENTS.

(*Zeitschrift für Elektrotechnik, Vol.* 4, *Pt.* 4, *April,* 1886, *pp.* 175–88.)

The author holds a brief for the alternate-current machine, and he argues that it is in all respects save one not only equal, but superior, to continuous-current machines. The one exception is for electro-chemical work, where the current must necessarily be in one direction only. Otherwise alternate-current machines are better; they are easier to build, they have no commutator to wear out, they generally run at a lower speed, they can be arranged to give almost any desired E.M.F., and they are specially suitable for working the Zipernowski-Déri system of transformers.

LIST OF UNABSTRACTED ARTICLES.

(*Philosophical Magazine*, 1886.)

April.—**A. P. LAURIE**—E.M.F. developed during the Combination of Zinc and Iodine in Presence of Water. **G. GORE**—Peltier Effect at Different Temperatures.

May.—**LORD RAYLEIGH**—Reaction upon the Driving Point of a System executing Forced Harmonic Oscillations of Various Periods, with Applications. **LORD RAYLEIGH**—Self-Induction and Resistance of Straight Conductors. **J. H. POYNTING**—Discharge of Electricity in an Imperfect Insulator.

(*Nature.*)

April 22, 1886.—*Anon.*—Use of Models for Instruction in the Magnetism of Iron Ships.

May 6, 1886.—**BALFOUR STEWART**—Madras Magnetical Observations.

(*Proceedings of the Royal Society.*)

February 11, 1886.—**W. M. BAYLISS and J. R. BRADFORD**—Electrical Phenomena accompanying the Process of Secretion in the Salivary Glands of the Dog and Cat. **J. EWING**—Effects of Stress and Magnetisation on the Thermo-electric Quality of Iron.

March 25, 1886.—**S. BIDWELL**—Changes produced by Magnetisation in the Length of Iron Wires under Tension.

April 15, 1886.—**J. and E. HOPKINSON**—Dynamo-electric Machines.

(*Electrical Review of New York.*)

April 3, 1886.—*Anon.*—New Galvanometer and Rheostat. *Anon.*—Telethermometer and Telehydrobarometer.

April 10, 1886.—*Anon.*—Schaefer Incandescent System and Dynamo.

April 17, 1886.—**W. D. MARKS**—Electric Railways.

May 1, 1886.—*Anon.*—Waterhouse Electric Light System. *Anon.*—Martin-Wilson Automatic Fire Alarm.

May 8, 1886.—*Anon.*—Magneto-electric Signal for Railway Crossings.

(*Electrician and Electrical Engineer*, 1886.)

April.—**CARL HERING**—Diameters of American Gauge Numbers.

(*Comptes Rendus, Vol.* 102.)

No. 11.—**LIPPMANN**—Absolute Spherical Electrometer. **G. SZARVADY**—Theory of Dynamo Machines used as Motors. **E. BICHAT** and **R. BLONDLOT**—An Absolute Electrometer with Continuous Readings. **STIELTJES**—The Number of Poles at the Surface of a Magnetic Body. **LE CHATELIER**—Changes produced by a Variation of Temperature in the E.M.F. of Thermo-electric Couples.

(*Journal de Physique*, 1886.)

April.—**E. MERCADIER**—Theory of the Telephone. **L. PILLEUR** and **E. JANNETTAZ**—Experiments in Thermo-Electricity.

(*La Lumière Electrique*, *Vol.* 19.)

No. 11.—**B. MARINOVITCH**—Organisation of the Fire Brigade at Chicago. **G. KAPP**—The Present Dynamos for Continuous Currents. **E. GIMÉ**—New Method for Overcoming Induction on Telephone Circuits.

No. 12.—**P. CLEMENCEAU**—Electric Communication on Trains of the French Railways. **G. RICHARD**—High-speed Steam Engines. **J. B. BESHIR**—Proposal for an Electric Tramway.

No. 13.—**E. DIEUDONNÉ**—Absolute and Practical Electro-magnetic Units. **G. KAPP**—The Present Dynamos for Continuous Currents. **G. RICHARD**—Electric Steering Gear.

No. 14.—**G. RICHARD**—High-speed Steam Engines. **E. DIEUDONNÉ**—New Forms of Galvanometers. **B. MARINOVITCH**—Wenstrom's Dynamo. **MAGUNNA**—Probable Future of Grove's Gas Battery considered as a Source of Electric Energy.

No. 15.—**A. DE LODYGUINE**—Note on Arc Lamps and Glow Lamps. **L. PALMIERI**—New Experiment to show that Electricity is Developed when Water is Vaporised. **G. PELLISIER**—The First Steps of Static Electricity.

No. 16.—**LEBLANC**—Study of the Multiplex Telephone. **W. C. RECHNIEWSKI**—Study of Dynamo Machines. **B. MARINOVITCH**—Wenstrom's Dynamo. **E. DIEUDONNÉ**—Absolute and Practical Electro-magnetic Units.

(*L'Electricien*, 1886.)

No. 158.—**E. HOSPITALIER**—Reforms to be Introduced into the Terminology of Physical Science. **E. HOSPITALIER**—Industrial Accumulators, and the Cost of a Watt.

No. 159.—**R. S.**—Electrical Haulage at the Antwerp Exhibition.

No. 160.—**G. CHAPERON**—Short Wire Potentiometer. **R. S.**—Electrical Haulage at the Antwerp Exhibition.

No. 161.—**E. HOSPITALIER**—Electric Lighting of Bourganeuf.

No. 162.—*Anon.*—Domestic Electric Lighting, chiefly by Batteries.

(*Bulletin de la Société Internationale des Electriciens*, 1886.)

March.—**P. BARBIER**—The Button Telephone. **Dr. BOUDET**—Photographic Reproduction of the Luminous Effects of Electricity without Photographic Apparatus.

April.—**LIPPMANN**—Absolute Spherical Electrometer. **LACOINE**—New Method of Testing for an Earth Fault on a Cable.

(*Journal Telegraphique de Berne*, 1886.)

No. 4.—**VUKOVIC**—Dependence of the Deviations of a Magnetic Needle on Earthquakes. **DELFIEU**—Improvements in Morse Apparatus so as to make it work a Bell.

(*Annalen der Chemie und Physik*, 1886.)

No. 4.—**Dr. A. VON WALTENHOFEN**—The Formulæ of Müller and Dub for Cylindrical Electro-Magnets. **H. LORBERG**—Remark on Two Corollaries of Hertz and Aulinger on a Point of Electro-Dynamics. **G. KIRCHHOFF**—On the Theory of the Distribution of Electricity on Two Conducting Spheres.

No. 5.—**E. RIECKE**—Pyro-Electricity of Tourmaline.

(*Beiblätter*, 1886.)

No. 3.—**KIESSLING**—On the Use of Influence Machines. **R. LEWANDOWSKI**—New Portable Chromic Acid Battery for Use with an Electric Cautery. **A. DUPRÉ**—Galvanic Cell. **A. DE GRAMONT**—Absence of Pyro-Electricity in Crystals of Sulphate of Magnesia and Sulphate of Cobalt. **C. FRIEDEL and A. DE GRAMONT**—Pyro-Electricity of Scolecite. **NOACK**—An Apparatus for showing the Laws of Oersted and Ampère. **C. MARANGONI** — Paramagnetism and Diamagnetism. **JORDAN**—On the Question of the Source of the Atmospheric Electricity.

No. 4.—**L. PALMIERI**—New Research for proving the Production of Electricity on the Condensation of the Aqueous Vapour of the Surrounding Medium. **A. BARTOLI and G. PAPASOGLI**—Electrosynthesis of some New Derivatives of Mellogen. **E. SEMMOLA**—Secondary Electrolysis. **C. TOSCANI**—Inner Chemical Work of Batteries. **D. TOMMASI**—Thermo-chemical Reactions. **W. F. NÖLLNER**—New Galvanic Cell. **O. ROSI**—Battery with Means for Heating the Liquid. **P. JABLOCHKOFF**—Regenerative Cell. **M. D. NAPOLI**—Cells of Erhard and Vogler. **G. A. SCHILLING**—Production of a Homogeneous Magnetic Field in the Tangent Galvanometer for Measurement of Strong Currents. **J. STÖSSEL**—Magnetic Moments produced in Soft Iron by Variable Induced Currents. **P. GRÜTZNER**—Electrolytic Action of Induced Currents. **W. WINTER**—Dimensions of the Derived Quantities of the Absolute System. **A. VON WALTENHOFEN**—Conductivity of the Gastein Mineral Springs. *Anon.*—New Demonstration Telephone.

(*Centralblatt*, 1886.)

No. 7.—**Dr. EDELMANN**—New Ammeter and Voltmeter for Working Use.

No. 8.—*Anon.*—Method of Testing for Contact of Two Wires. **Dr. W. A. NIPPOLDT**—Telephone Bridge Pocket Testing Apparatus. **H. F. WEBER**—Criticism of Hughes's Latest Discoveries in Induction.

No. 9.—**AVERDIECK**—Differentially-wound Bell.

No. 10.—**R. SCHORFHAUSEN**—Calculation of the Magnetic Moment of Electro-Magnets.

No. 11.—**HERMANN MÜLLER**—Measurement of the Work of Dynamos. **G. WEHR**—Pollak's Regenerative Cell.

(*Elektrotechnische Zeitschrift*, 1886.)

March.—**C. FRISCHEN**—New Apparàtus for Registering the Speed of Trains. **R. v. FISCHER-TREUENFELD**—Spanish Military Telegraphs. **E. ZETSCHE**—Translation with Estienne's Duplex Writer. **GRAWINKEL**—System of Cells for Telephone Stations. **SCHÄFER and MONTANUS**—Ader's New Patent Microphone. **RÜHLMANN**—Hydrometric Measurement of Currents and E.M.F. **W. PEUKERT**—Measurement of the Electro-Magnets of a Compound-wound Dynamo. **G. WEHR**—Pollak's Regenerative Cell. **RÜHLMANN**—Manufacture of Accumulators.

May.—**Dr. TH. BRUGER**—Experiments on the Action of Solenoids on Variously-shaped Cores. **Dr. M. KRIEG**—New Formulæ for Electro-Magnetism. *Anon.*—The Button Telephone. **F. HELLER**—The Telephone for House Use. **E. ZETSCHE**—Loop Connection for Fire Telegraphs.

(*Zeitschrift für Elektrotechnik*, 1886.)

April.—**Dr. A. VON WALTENHOFEN**—The Torsion Galvanometer of Siemens and Halske. **R. v. FISCHER-TREUENFELD**—Military Telegraphs. **M. BURSTYN**—Electric Fuzes for Mines. **Dr. A. VON WALTENHOFEN**—Conductivity of the Gastein Mineral Waters.

JOURNAL

OF THE

SOCIETY OF

Telegraph-Engineers and Electricians.

Founded 1871. *Incorporated* 1883.

VOL. XV. 1886. No. 63.

FURTHER HISTORICAL NOTES ON THE ELECTRIC LIGHT.

(*Third Article.*)*

By Colonel Sir FRANCIS BOLTON, V.-P., Hon. Secretary.

On May 14th, 1879, I had the honour of bringing before the Society a paper to which I gave the title, "Some Historical Notes on the Electric Light." The general interest which was then evinced in the subject induced me to continue my historical compilation, as I was gratified to find that it was considered to possess a special value; and in November, 1882, I again submitted a further paper to a meeting of the Society, in which the history of electric lighting was brought down to September of that year, and included all, or very nearly all, the specifications of patents relating to the electric light which had been published to that date. These papers principally consisted of short abstracts of

* First Article, Journal of the Society, part 27, vol. VIII., p. 217; Second Article, part 44, vol. XI., p. 413.

each specification, selected from the collection in the Library of the Society, and classified under certain headings, the object being to facilitate reference and to render it less difficult than formerly to find any particular class of patent required.

The space at my disposal being limited, the abstracts made were necessarily short, while the miscellaneous nature of the materials which I had to collate rendered the work of classification one of considerable labour.

In the present paper I have brought the subject up to May last. The compilation is based on the same system as the paper I read before the Society on the 9th November, 1882, and the classification is somewhat similar.

I have to regret the large number of specifications placed under the division "Miscellaneous," but owing to the complex nature of a very large number of the specifications to be dealt with, it was found impossible to otherwise describe them. This will account also for many of the patents being apparently wrongly classified, and cross references have been somewhat freely used where necessary.

SUBDIVISION I.

DYNAMO- AND MAGNETO-ELECTRIC MACHINES.

I.—OF THE WILDE TYPE.

1882. J. S. WILLIAMS. **1174.**

See Subdivision of the Current.

1882. R. MATTHEWS. **1201.**

Improvements in the Construction of Dynamo-Electric or Magneto-Electric and Electro-Dynamic Machines.—(Provisional.)

A number of permanent or electro-magnets arranged in a circle, cores made of iron strips; revolves field coils and armature in opposite directions. Describes the use of an odd number of coils in the armature to what there is in the field.

1882. D. T. PIOT. **1692.**

Improvements in Dynamo-Electric or Magneto-Electric Machines.

The armature consists of a number of bobbins arranged on the periphery of a disc, with the axes of the bobbins parallel to the axis of machine. A series of the armature coils are arranged to revolve between the poles of the field electro-magnets at one time.

1882. D. A. CHERTEMPS and L. DANDEU. **1747.**

Improvements in Dynamo-Electric Machines.

The armature is arranged with coils fixed to the periphery of a disc, with their axes parallel to the axis of machine; the field magnets of similar construction. Describes also the field electro-magnets revolving and having the armature fixed.

1882. J. FARQUHARSON. **2771.**

An Improvement in Dynamo-Electric Machines.

Describes armature constructed with coils on periphery of a disc, with their axes parallel to axis of machine. Also describes field magnets of similar

construction. The iron cores of both armature and field electro-magnets are oval in section.

1882. S. HALLETT. 2573.

A New or Improved Dynamo-Electric Machine, certain Improvements whereof are applicable to and in the Construction of Dynamo-Electric Machines generally.

Upon a shaft are placed circular rings upon which are bolted armature magnets standing out radially therefrom.

1882. J. E. H. GORDON. 2871.

Improvements in Dynamo-Electric Machines.

Improvements to Patent No. 78, 1881.

Relates to improvements in the mechanical construction of the machine.

1882. R. MATTHEW. 3334.

Improvemens in the Construction of Dynamo-Electric or Magneto-Electric and Electro-Dynamic Machines, and in Governing and Regulating the same.

Describes machine having armature coils wound with their axes parallel to axis of machine, and which may be wound with wire, bars or strips, arranged without any cores, so that the air may pass through the coils. A number of electro-magnets are arranged on both sides of the armature coils so as to present any number of magnetic fields of like polarity.

1882. W. P. THOMPSON. 3420.

(From P. Payen and A. Sandron.)

Improvements in Dynamo-Electric Machines.

Armature consists of a number of coils of wire arranged on the periphery of a wheel, with their axes parallel to axis of the machine. Similar coils for field magnets are arranged on both sides of the armature, with their ends facing the ends of armature coils.

1882. A. LALANCE and M. BAUER. 4555.

Improvements in Dynamo-Electric Engines.—(Provisional.)

Relates to the more accurate construction of machines where the field electro-magnets are arranged on the framework with their axes parallel to the machine, the axes of the armature coils being also parallel to the axis of the machine, and arranged with their poles to revolve between the two sets of field electro-magnets.

1882. E. JONES. 5092.

Improvements in Electric Generators.—(Provisional.)

Describes a machine with coils rotating in front of other fixed coils with their axes parallel to axis of machine.

1882. W. S. HORRY. **6019.**

Improvements in Dynamo-Electric Machines.

Describes pear-shaped coils which are built up wheel shape, the axis of the coil being parallel to machine. Similar shaped field electro-magnets are placed on both sides of the armature coils.

1883. H. H. LAKE. **184.**

(From C. L. R. E. Menges.)

Improvements in and relating to Dynamo- or Magneto-Electric Machines and Apparatus to be employed in connection therewith.

Relates to machines with the armature coils and field magnet coils constructed with their axes parallel to axes of machines, and describes various methods of winding same.

1883. R. ROWAN and S. WILLIAMS. **792.**

Improvements in Dynamo-Electric Machines and Electric Motors, and in Electric Current Distributors.

Improvements to Patent 49, 1883.

Describes armature constructed of a disc of hard wood, with holes cut through, in which are inserted two sets of coils of insulated wire, the set on one side overlapping those on the other side by half the diameter of a single coil. Also relates to the formation of an armature with the wires arranged in a zigzag shape. The field electro-magnets are arranged on each side of the armatures, with their axes parallel to axis of machine.

1883. F. WYNNE. **797.**

Improvements in Dynamo-Electric and Magneto-Electric Machinery, and in Gearing for use therewith.—(Provisional.)

Relates to rotating the armature in an opposite direction to that of field electro-magnets in machines where the coils are placed with their axes parallel to axis of machine, or with armature coils wound on an annular core.

1883. H. T. BARNETT. **804.**

Improvements in the Construction of Dynamo-Electric Machines, partly applicable also to other purposes.

Describes machine with coils constructed with their axes parallel to axis of machine, the coils being pear-shaped. Also relates to use of magnetic compound for the cores of armature coils.

1884. W. A. LEIPNER. **1291.**

Improvements in the Armatures of Dynamo-Electric Generators and Motors, whereby their construction is simplified and cheapened, and they are rendered more efficient and less liable to become heated.—(Provisional.)

Describes a form of armature in which the coils are placed on the periphery of a non-metallic disc, with their axes parallel to the axis of machine; the coils are wound on V-shaped cores, and placed on each side of the disc.

1884. W. A. CARLYLE. **2006.**

Improvements in Dynamo-Electric Machines.—(Provisional.)

Describes the use of an air fan on the armature axis. Relates also to the construction of the poles of field magnets. Also describes the use of the cores of armature magnets of square or diamond shape.

II.—OF THE GRAMME TYPE.

1882. R. KENNEDY. **1640.**

An Improved Dynamo-Electric Machine.

This patent has for its object the providing for four, eight, or other even number of fixed magnetic poles greater than two, and to generate electricity as the armature is passing between two similar poles as well as between dissimilar poles.

1882. J. B. ROGERS. **1760.**

Improvements in the Arrangement of "Dynamo" or Electric Current-producing Machine.

The armature consists of an annular core around which the coils are placed; between the coils solid polar extensions are fitted; revolves between fields arranged on each side of armature coils.

1882. E. L. VOICE. **1794.**

Improvements in the Means or Apparatus for Generating Currents of Electricity.

Describes revolving armature with annular core, and attached to a spindle adjacent to one pole of permanent or field electro-magnet. The coils of wire on the annular core are surrounded by the poles of the other end of the permanent or electro-magnets. Several methods of arranging the above are shown.

1882. HON. R. BROUGHAM. **2044.**

Improvements in Dynamo-Electrical Machines.

Describes coils of Gramme machine wound with flat copper ribbon instead of wire.

1882. S. H. EMMENS. **2349.**

Improvements in Electrical Apparatus.

Describes armature composed of a number of single electro-magnet coils arranged end to end and forming a ring of coils. The field magnets embrace the periphery of a circular space in which the armature revolves, north poles being on one side, and south poles on the other; the spindle of machine is hollow. Proposes the use of a magnet with an arc lamp, the carbon points being in vacuum or in a glass receiver filled with a non-oxidising vapour or gas. Arranges the carbon points in the magnetic field, thereby increasing the radiating surface of the light.

1882. R. WERDERMAN. 2364.

Improvements in Dynamo-Electric Machines.

Armature core consists of an iron cylinder, the metal consisting of an alloy of iron, nickel, and cobalt; the coils being wound on this cylinder.

The field magnets consist of a series of polar extensions projecting inwardly and from an iron cylinder which surrounds the armature; between the polar extensions the wire of field electro-magnets are wound.

The commutator is arranged at the end of the armature and at right angles to the shaft.

1882. A. J. JARMAN. 2565.

Improvements in Dynamo-Electric Machines.

Employs hollow concentric iron cylinders wound with wire to form the armatures. One armature as above described is placed at each end of field electro-magnets, the poles of which embrace the armatures.

1886. R. E. B. CROMPTON. 2618.

Improvements in Dynamo-Electric Machines.

Employs disc or ring of metal wound in a system of step-by-step winding.

1882. J. BLYTH. 2661.

Improvements in Apparatus for Producing Electric Currents, and in Apparatus for Measuring such Currents.

Employs coils wound on an annular core, and secured in position by iron links placed between the coils; polar extremities of separate field electro-magnets are placed in the inner part of armature, and polar extremities of another field electro-magnet are placed outside the armature.

Employment of a non-volatile gas meter arranged in combination with electrolytic apparatus.

1882. F. L. WILLARD. 2803.

Improvements in Dynamo-Electric Machines.

Describes a machine whose armature is constructed of a solid annular core upon which the coils are wound; solid ends or cheeks are fitted between the coils. Several armatures as thus constructed are mounted on one shaft, which revolves between two polar extensions of field electro-magnets.

1882. J. A. BERLY. 2885.

(From F. V. MAQUAIRE.)

Improvements in Dynamo-Electric and Electro-Dynamic Machines.

The armature consists of two annular cores placed side by side on each core are wound coils of wire; the coils revolve between two series of inductors.

1882. T. PARKER and P. B. ELWELL. 2917.

Improvements in Dynamo-Electric Machines and Electro-Motors, and in the Means of Storing the Energy of the Electric Current.—(Provisional.)

An armature is described with coils made and arranged so as to resemble the rim of a fly-wheel, the rim and sides being embraced by the field magnets.

Describes use of rollers instead of brushes for collecting the current from the commutators.

Describes also electrodes for storage batteries, arranged with strips of lead built up in a zigzag form and fitted to a frame of wood, the spaces between being filled with oxide of lead.

1882. J. H. JOHNSON. 2990.

(From La Compagnie Électrique of Paris.)

Improvements in Apparatus or Machinery for Generating, Controlling, and Utilising Electric Currents.

The apparatus described is used more especially for reproducing power through electric agency, and describes the modification of the field magnets of Gramme machine so that four polar extensions completely embrace the armature.

Current-regulating apparatus is also described where a solenoid core is made to raise and lower a number of contact-pieces in mercury cups to which are connected resistances.

1882. SPERRY. 3025.

See Lamps—Arc—Vertical Carbons.

1882. W. E. AYRTON and J. PERRY. 3036.

Improvements in Dynamo-Electric Machines.

Describes a machine with armature coils wound on an annular iron core; the field electro-magnets are provided with four polar extensions which embrace the armature. Special methods of joining up the coils on the armature are described, also the placing of the coils obliquely on the armature.

1882 A. LÉVY. 3181.

(From D. Lachaussée.)

Improvements in Dynamo-Electric Machines.—(Provisional.)

Armature consists of a number of electro coils placed end to end and forming a ring, and rotating between four, six, eight, or more, magnetic points.

1882. J. M. M. MUNRO. 3322.

Improvements in Apparatus for Producing, Measuring, and Distributing Electric Currents.

Coils of wire wound on an annular core are constructed to form the armature; a number of such armatures are arranged on one shaft, and are made

to rotate between poles of field magnets in such a manner that the outer face, and also the two sides of the coils, are under the influence of the magnetic field.

Various sections of coils and fields are shown for effecting this.

Apparatus is also described for changing the direction of the current, and also for automatically throwing the dynamo out of circuit when it ceases to be driven.

An apparatus for measuring electric currents is also described.

Various switches are also illustrated.

1882. A. RECKENZAUN. **3473.**

Improvements in Apparatus for Generating, Utilising, and Regulating Electric Currents for Lighting and other Purposes.—(Provisional.)

The armature is constructed of iron rings, each of which is formed of a number of sheet-iron washers; these washers have as many projecting parts as there are bobbins in a ring, and are capable of revolving close to polar extensions of the field magnets.

Describes a lamp constructed with a cylinder or chamber in which water or air is confined; by means of a suitable inlet and outlet the movement of the carbons are regulated.

1882. H. H. LAKE. **4111.**

(From S. F. VAN CHOATE.)

Improvements in Dynamo-Electric Machines.

The armature coils are wound on a solid annular core, with projecting poles between each coil. The uprights forming the framing of the machine are constructed to form the field electro-magnets, with polar extensions extended for one polarity to embrace the upper half of the armature, and the opposite polarity the lower half.

1882. M. DEPREZ. **4376.**

Improvements in Dynamo-Electric Machines.

Describes improvements in the details of construction of the parts of dynamos of the Gramme type.

1882. A. B. SENNETT. **4492.**

Improvements in Apparatus for Producing and Regulating Electric Currents for the Production of Electric Light, and in Lamps, Fittings, and Apparatus employed therewith, &c.

Describes dynamo with armature constructed after the Pacinotti type, but designed more especially to give to the ring such a form that the conductor shall only be in contact with those portions which are indued with a polarity tending to produce a current in the required direction, and also designed to prevent the circulation of the so-called Foucault currents.

A system of electric lighting is described where dynamos are used in conjunction with main and auxiliary accumulators; also an arrangement for regulating the intensity of magnetic field of generator, &c.

Details of construction of switches, and lamp and sockets, are described.

An arc lamp is described in which the upper carbon rod is in the form of a screw thread, the regulation being effected by releasing a lock nut which is fitted to same.

Also describes lamp where the carbons are placed in a block of refractory material.

1882. P. CARDEW. **5105.**

Improvements in Electric Lighting, and in Apparatus connected therewith, partly applicable to other purposes.

Describes dynamo-electric machines in which the main current is conveyed through the magnetising coils, these coils being formed of a number of insulated conductors, each connected at one end to one of the armature brushes, whilst the other ends of the several conductors are coupled to separate terminals, to each of which a separate wire may be connected.

Also relates to an arc lamp provided with a wheel train for regulating the carbons.

1882. C. A. McEVOY and J. MATHIESON. **5631.**

Improvements in Dynamo-Electric Machines.

The annular core on which the coils are wound is supported in U-shaped spokes of a non-magnetic material, and which radiate from the shaft.

A ribbon of soft iron is used for the core.

The poles of the field magnets are provided with a groove or channel, so that the surface of the armature coils may be in close contiguity to poles.

1882. W. A. BARLOW. **5783.**

(From W. E. Fein.)

Improvements in Magneto- and Dynamo-Electric Machines.—(Provisional.)

Describes a machine in which an annular core is constructed of thin iron discs attached to a star-shaped piece which is fitted on to the axle. The coils are placed on this core and embraced in pole-pieces of the field magnets; the pole-pieces are provided with half funnel-shaped arms, which enter into the inner space of the ring.

1882. R. MATTHEWS. **6146.**

Improvements in Dynamo-Electric, Magneto-Electric, or Electro-Dynamic Machines.

Describes the construction of an armature of the Gramme type, the wire strips being made to describe an irregular coarse pitch thread around the annular core.

1882. A. M. CLARK. **6164.**

(From L. Gerard and W. V. Bonsor.)

Improvements in Apparatus for the Production of the Electric Light.

Relates to the simplifying of the construction of a machine where the armature coils are wound on an annular core.

Also describes using several such armatures in one machine.

1883. **F. J. CHEESBROUGH.** 1.

(From E. R. Knowles.)

Improvements in Dynamo-Electric Machines.

The annular iron core of the armature consists of two or more concentric rings; coils are wound on this core between solid iron cheeks; the polar extremities of the field magnets are formed with a channel in which the armature coils rotate.

1883. **J. S. WILLIAMS.** 24.

See Subdivision of the Current.

1883. **T. ROWAN and S. WILLIAMS.** 49.

Improvements in Dynamo-Electric Machines and Electric Motors.

Describes an armature constructed with thin flat wire, and wound spirally until made of required dimensions; the field electro-magnets are brought with the poles in close proximity to both sides of the armature, the axes of the field magnets being parallel to the axis of machine.

1883. **W. P. THOMPSON.** 1991.

(From B. Cabella.)

Improvements in the Construction of Dynamo-Electric Machines, and in Bobbins or Gramme Rings therefor.

Describes the construction of an armature with the insulated conductor wound on an annular core; the non-useful part—*i.e.*, the part farthest from the exciting magnets, or the weakest part of the magnetic field—is of much larger section than the useful part, or the part that is nearest the exciting magnets, and in which the useful induction actually takes place.

1883. **R. D. BOWMAN, J. E. L. CLARK, and W. J. K. CLARK.** 1113.

Improvements in Electric Generators.

Describes details of construction of a machine with coils wound on an annular core.

1883. **M. DEPREZ.** 1736.

Improvements in Dynamo-Electric Machines of Pacinotti's sort.

The annular core is built up of a number of semi-circular iron plates so that the coils can be readily placed on it; one set of coils are placed on the core, and another set are placed so as to fill up the gap left between the outer cheeks of the first set of coils; the inner portion of the second set of coils overlaps the inner portion of the first set.

1883. **A. M. CLARK.** 2044.

(From La Société Solignac et Cie.)

See Dynamo- and Magneto-Electric Machines of the Siemens type.

1883. W. HOCHHAUSEN. **2058.**

Improvements in Magneto- and Dynamo-Electric Machines, and in Apparatus connected with the Development and Regulation of Electric Currents.

Relates to machines with armature coils wound on an annular core formed of bars screwed together; two poles of field magnets embrace the armature.

A motor for moving the commutator brushes is actuated by the strength of current in external circuit.

1883. S. PITT. **2205.**

(From L. Daft.)

Improvements in Dynamo Machines and Lamps connected therewith.

In this machine the armature is constructed with coils wound on an annular core, each coil having a thin plate of magnetic material between the layers of wire, for the purpose of producing a magnetic field and concentrating the induced magnetism in immediate proximity to the wire.

Also describes lamp, the upper carbon-holder consisting of a plain rod which passes between two cams which are attached to levers; the rod passes through a hollow core contained in a solenoid; when the core is raised it moves the levers carrying the cams and lifts the rod.

Also describes the use of a secondary or differential coil of wire wound on the core.

Also describes an arrangement for lifting the cams by electro-magnets instead of solenoid.

1883. O. WILLIAMS. **2250.**

Improvements in Dynamo-Electric Machines.

Relates to arranging the magnetic fields in a machine where the armature is constructed with coils on an annular core, the magnetic fields being formed by the juxtaposition of four magnetic poles, two north and two south, and so arranged that the two north poles and the two south poles act together, and allow of the circle of magnetism being complete at any portion of the rotating armature.

Also describes use of two or more series of concentric armature rings, also of ring-shaped horse-shoe induced electro-magnets placed alongside the armature.

1883. H. H. LAKE. **2339.**

(From A. M. Loryea.)

Improvements in and relating to Dynamo-Electric Machines.

Relates to simplifying the construction of a machine in which the armature coils are wound on an annular core; also relates to the construction of the field magnets which surround same

1883. H. H. LAKE. 2768.

(From R. E. BALL.)

An Improved Method of and Apparatus for Generating Electric Currents, which Apparatus may also serve as an Electro-Motor.

Combines and arranges two or more "Pacinotti" armatures or similar elements so as to mutually induce continuous electric currents in each other.

1883. S. PITT. 3001.

(From N. H. EDGERTON.)

Improvements in Dynamo-Electric Machines, Systems of Electrical Currents, and Means for Producing, Controlling, and Reinforcing said Currents.

Describes armature coils wound on an annular core, with projecting pieces between each coil. Bipolar fields embrace the armatures.

1883. J. L. CLERC. 3444.

Improvements in Electric Lighting Apparatus, and in the Means for Generating, Regulating, and Measuring the Electric Currents.

Employs armature coils wound on an annular core and between iron cheeks which are provided with projections placed at right angles to each coil.

1883. E. JONES. 3633.

Improvements in Machines for Obtaining Electric Currents.

Describes armature coils wound on annular core divided radially by pole-pieces into fan-shaped sections.

1883. H. J. ALLISON. 3735.

(From R. N. KING.)

Improvements in Electro-Dynamic Machines.—(Provisional.)

Relates to armatures with coils wound on an annular core of U-shaped section.

1883. H. H. LAKE. 4177.

(From G. W. FULLER.)

Improvements in Dynamo-Electric Machines.

Relates to simplifying the construction of armatures where the coils are wound on an annular core, the iron core being formed of a cylindrical spiral.

1883. W. M. MORDEY. 4419.

Improvements in Dynamo-Electric Machines.

Relates to the construction of iron cores for armatures in which the coils are wound on annular core, and are constructed, firstly, by taking a number of iron rings placed side by side, but separated by slips or washers, and, secondly, by taking a number of hoops arranged concentrically one within another, and insulated from each other.

1883. SIR W. THOMSON. 4617.

Apparatus for Generating, Regulating, Measuring, Recording, and Integrating Electric Currents.

Describes in machines whose armatures are constructed with the coils wound on an annular core, the construction of the core of square iron wire wound spirally; also the wire used for the coils is square in section.

1883. H. J. HADDAN. 4563.

(From C. F. BRUSH.)

Improvements in Armatures for Electric Current Generating Machines.

Relates to the construction of the iron core of an armature where the coils are wound on an annular core, and which consists of an iron ribbon or band wound in the form of a spiral, and having plates interposed between the spirals and arranged to form cheeks between which the coils are wound.

1883. C. H. BENTON. 4885.

Improvements in Dynamo-Electric Machines.

Relates to the construction of an armature with coils wound on an annular core, the iron core being formed of rings of trough section being placed together; the troughs are filled with pieces of iron wire gauze filled with iron filings. The field magnets are constructed of a number of thin magnetic bars, having pole-pieces provided to embrace the armature.

1883. R. E. DUNSTON, A. PFANNKUCHE, and J. FAIRLIE. 5082.

An Improvement in Dynamo-Electric or Electro-Dynamic Machines.

Relates to the construction of the iron core of an armature where the coils are wound on an annular core, and which consists of iron hoop wound in convolutions along with interposed insulating material.

1883. H. J. HADDAN. 5238.

(From BAIN ELECTRIC Co.)

Improvements in Electric Generators.

Relates to the construction of a machine the armature coils of which, are wound on an annular core. The field magnets consist of two semi-circular cores having two polar extensions which embrace the armature. Various methods of connecting up wires on machine are described.

1883. H. H. LAKE. 5470.

(From T. J. MCTIGHE and J. T. MCCONNELL.)

Improvements in and relating to Dynamo-Electric Machines which can also be used as Electric Motors.

Relates to the construction of field magnets for embracing an armature with the coils wound on an annular core.

1883. **P. W. WILLANS.** **5736.**

Improvements in Dynamo-Electric Machines.—(Provisional.)

Relates to armatures constructed with coils wound on annular cores, and describes various methods of arranging the armatures with regard to field magnets.

1884. **C. F. COOPER.** **572.**

Improvements in the Armatures of Dynamo Machines.

Relates to the construction of an armature with the coils wound on a cylinder of soft iron built up of a series of rings, the wire passing parallel to the axis within and without the cylinder.

1884. **T. PARKER and P. B. ELWELL.** **770.**

Improvements in Dynamo-Electric Machines, and in the Method of Constructing the Armatures thereof.—(Provisional.)

Relates to armatures constructed with a core made up of iron wires or iron rings in the form of a cylinder; the wires of the coils are wound longitudinally inside and outside the iron core.

1884. **J. RILEY.** **1584.**

Improvements in Magneto- or Dynamo-Electric Machines.—(Provisional.)

Describes the construction of an armature with the coils wound on an annular core of solid metal with projections on each side, and provided with pole-plates at the outer ends of these projections.

1884. **M. H. HURRELL.** **1789.**

Improvements in Dynamo-Electrical Machines.—(Provisional.)

The annular core on which the coils are wound is constructed of a spherical or convex form, also the faces of the pole-pieces of a corresponding concave form. Also describes details of the construction of the commutator, &c.

1884. **T. PARKER and P. B. ELWELL.** **2544.**

Improvements in the Armatures of Dynamo-Electric Machines.—(Provisional.)

Improvements to Patent No. 770, 1884.

Relates to the winding of an annular core with a single layer of wire.

1884. **J. H. GREENHILL.** **3570.**

Improvements in Dynamo-Electric Machines.—(Provisional.)

Uses an armature with the coils wound on an annular core, the core being built up of segments of iron to form a ring. A number of rings thus built up are held by spokes projecting radially from the shaft.

1884. R. E. B. CROMPTON. **4302.**

Improvements in Dynamo-Electric Machines.—(Provisional.)

Describes the construction of an armature with the coils wound on an annular core, the core being built up of rings cut from sheet iron and of great radial depth; radial bars carry the iron core on the shaft; the external winding on the coil is of small radial depth, and the internal winding is of great radial depth.

1884. W. R. LAKE. **4721.**
(From C. Richter.)

Improvements in Dynamo-Electric Machines.

Describes the construction of field magnets for dynamo having convexo-concave sides, and having lateral flange-shaped projections which form cores upon which are wound exteriorly the wire.

The armature is constructed with the coils wound on an annular core of iron wire.

1884. Sir W. THOMSON and S. Z. DE FERRANTI. **5335.**

Improvements in Dynamo-Electrical Machines.—(Provisional.)

Describes a machine for producing alternating currents, and in which the currents are led off by two insulated conductors; a disc secured to each conductor, and having its circumference and outer parts of its sides surrounded by a trough ring containing mercury.

1884. W. E. GEDGE. **7032.**
(From C. J. van Depoele.)

Improvements in Dynamo-Electric Machines.

Relates to the special construction of parts, and the mode of winding and connecting the armature and field magnet coils in a machine in which the armature coils are wound on an annular iron core.

1884. E. JONES. **7185.**

Improvements in Dynamo-Electric Machines.—(Provisional.)

Relates to the construction of a machine with a single standard or end-plate carrying a single long bearing. A pair of electro-magnet field coils are arranged with their cores parallel to axis of machine, and having deeply-channelled pole-pieces, within and between which the armature rotates, and is constructed with coils wound on an annular core.

1884. A. SHIPPEY and J. E. WYDER. **9365.**

Improvements in Magneto-Dynamo Electric Generators or Electro-Dynamo Magnetic Machines.—(Provisional.)

The armature of this machine is constructed with the coils wound on an annular core.

Three sets of compound permanent magnets surround the armature. Relates also to the use of welded and compressed steel in these magnets.

1884. R. E. DUNSTON. **9536.**

An Improvement in the Ring Armature of certain Dynamo-Electric or Electro-Dynamic Machines.

Describes a method of attaching to the ring armature a separate wedge-shaped saddle-piece of iron between the outer ends of the coils.

1884. R. P. SELLON and J. S. SELLON. **11393.**

Improvements in the Construction of Armatures for Dynamo-Electric Machines.

Relates to the construction of an armature with the coils wound on an annular core, the annular core being constructed of spirals of iron band.

1884. L. J. GROVES. **13067.**

Improvements in Dynamo-Electric and Electro-Dynamic Machines.

Relates to the details of construction of an armature with the coils wound on an annular core.

1884. F. WYNNE and R. P. SELLON. **13810.**

Improvements in the Construction of Armatures for Dynamo-Electric Machines.

Relates to the construction of the core of iron strip wound spirally, the outer layer or layers of which are bent so as to form projections, between which the coils are placed.

1884. J. H. GREENHILL. **14829.**

Improvements in Dynamo-Electric Machines.

Describes an armature constructed with two iron annular cores fitted to one shaft, and each having coils wound thereon.

1884. W. MATHER, J. HOPKINSON, and E. HOPKINSON. **15648.**

Improvements in Dynamo-Electric Machines.

Describes the construction of the iron core of field magnets with greatly increased section of iron; also constructs an annular core for an armature of plates of iron insulated from each other.

1884. J. D. F. ANDREWS. **16916.**

An Improvement in Multipolar Electric Machines.

Describes a machine in which a coiled armature ring revolves through two, three, or more polar fields, connecting the coils of the ring to each other and to the commutator in such a manner that all the coils that are approximately in the same phase (*sic*) at the same time are made to act together.

1885. G. FORBES. **4120.**

Improvements in Dynamo-Electric Machines.

Describes construction of field magnets. The coils of wire are arranged inside a shell or cylindrical box, in which also the armature revolves; coils are wound on an annular core.

1885. F. WYNNE. **2325.**

Improvements in the Construction of Armatures for Dynamo-Electric Machines.

Describes the construction of iron annular cores of strips separated from each other by a space or an insulating material.

1885. A. M. CLARK. **3467.**

(From L. VISSIERE.)

Improvements in Dynamo-Electric Machines.

Describes forms and arrangements of armature and field magnets of machines with armature coils wound on an annular core or cylinder.

1885. J. A. BERLY. **14288.**

(From Z. T. GRAMME.)

Improvements in Dynamo-Electric Machines.

Constructs field magnets and frame in such a manner that one single hollow piece constitutes at one and the same time the bed-plate, the cores of the magnets, the pole-pieces, and one of the bearings.

III.—OF THE SIEMENS TYPE.

1882. W. R. LAKE. **1614.**

(From E. WESTON.)

Improvements in Magneto- or Dynamo-Electric Machines.

Employs two separate coils of wire which are wound together on a hub, the wires passing across from one side to the opposite side of the hub.

1882. C. W. VINCENT. **2340.**

(From W. B. F. ELPHINSTONE.)

Improvements in the Construction of Dynamo-Electric Machines.

Improvements to Patent 332, 1879.

Describes an improved method of constructing the armature, and also describes forming the hanks of the armature by winding them upon a rotating former," and moulding the same by heat and pressure.

Also describes armature with coils wound obliquely.

1882. W. R. LAKE. 2694.

(From E. WESTON.)

Improvements in Dynamo- or Magneto-Electric Machines.

Two systems of coils in diametrically separate divisions, the divisions of one system being alternately under and over those of the other system.

1882. W. R. LAKE. 3204.

(From E. THOMSON.)

Improvements in and relating to Apparatus for the Generation, Regulation, and Utilisation of Electric Currents.

Use of electro-magnetic attachment to dynamo, which adjusts the position of the commutator brushes to preserve a uniform current strength.

Arc lamp in which the upper carbon rod is regulated by a lever clutch.

Incandescent lamp of low resistance to be worked in series.

Dynamo with spherical armature; the field magnets are constructed with iron shells, and enclose the spherical armature; a regulator magnet is provided for moving the brushes, and a small rotary blower for furnishing an air-blast for the preservation of the commutator insulation.

1882. W. R. LAKE. 3685.

(From H. S. SAMPLE and F. RABL.)

Improvements in and relating to Dynamo-Electric Machines.

The object of this invention is to provide more powerful field magnets, and which are constructed with hollow cores, the armature being of Siemens type.

An automatic apparatus is arranged for adjusting the position of the brushes on the commutator.

1882. T. J. HANDFORD. 3756.

(From T. A. EDISON.)

Improvements in and relating to Dynamo- or Magneto-Electric Machines.

Relates to the deriving from the same commutator of a continuous current dynamo a main current having a tension due to the electro-motive force of all, or nearly all, the coils in the armature, and an auxiliary current having a lower tension due to the electro-motive force of a part only of the coils of the armature.

1882. W. R. LAKE. 4819.

(From J. WENSTRÖM.)

Improvements in Dynamo- or Magneto-Electric Machines.

Relates to machine with armature coils wound lengthwise on a drum or core, and embraced in polar extensions of field electro-magnets of special construction in the form of iron cylinders.

1882. H. H. LAKE. 5918.

(From R. H. Mather.)

Improvements in Dynamo-Electric Machines.

Describes an armature core composed of iron discs whose thickness does not exceed one-third of their diameter; coils of wire are wound crosswise on these discs. Also describes the making of the core of thin iron ribbon. Semi-circular polar extensions of field electro-magnets embrace the armature.

1883. F. H. RELPH. 316.

(From J. H. Olmstead.)

Improvements in Dynamo-Electric Machines.—(Provisional.)

The armature consists of five independent coils wound longitudinally on a cylindrical core; the field magnets have curved pole-pieces which embrace the armature.

1883. J. HOPKINSON. 973.

Improvements in Dynamo-Electric Machines.

Relates to the obtaining of a greater effect from existing dynamo machines, the improvements being applicable to machines having armatures of the form known as Siemens' armature.

1883. A. M. CLARK. 2044.

(From La Société Solignac et Cie.)

Improvements in Dynamo-Electric Machines.

Describes the construction of the iron cores of cylindrical armatures, with single or double enlargements of the core at diametrically opposite points.

1883. W. SIEMENS. 2210.

Improvements in Dynamo-Electric and Electro-Dynamic Machines, and in Appliances connected therewith for Measurement of Electric Power.

The special feature of this invention relates to field magnets. An armature of any known construction, having a non-magnetic core, is surrounded by a stationary coil of wire arranged as a meridian to the armature—*i.e.*, in a plane passing through the axis of revolution.

1883. A. CLARK. 2330.

Improvements in Magneto- and Dynamo-Electric Machines and Motors.—(Provisional.)

Describes armature with cores of Siemens type, bent or formed of S shape in cross section to present the greatest possible extent of surface on which the wire is wound. The poles of the field magnets are tapered on the face which surrounds the armature.

1883. H. H. LAKE. **4192.**

(From G. W. FULLER.)

Improvements in and relating to Dynamo-Electric Machines.

Describes the construction of the core of iron spirals for armatures having the coils which traverse the exterior longitudinally upon opposite sides.

1884. H. J. ALLISON. **131.**

(From R. N. KING.)

Improvements in Electro-Dynamic Machines.—(Provisional.)

Relates to the construction of an armature provided with air spaces between the coils, the wire being arranged longitudinally along the periphery of the core.

1884. S. WILLIAMS. **314.**

Improvements in Dynamo-Electric Machines.—(Provisional.)

Armature constructed with rectangular or sector-shaped coils wound on a hollow rectangular steel frame, the coils alternating right and left handed, and rotating between sector-shaped poles of field magnets alternating in sign.

1884. W. H. SCOTT and E. A. PARIS. **6261.**

Improvements in Dynamo-Electric Machines.—(Provisional.)

Describes the construction of an armature with conducting plates arranged longitudinally on the periphery of a drum; also describes method of connecting same across the ends of the drum.

1884. J. HOPKINSON and W. MATHER. **768.**

Improvements in Dynamo-Electric Machines.—(Provisional.)

In order to remove the heat generated in the armatures a fan is used, and is enclosed and arranged so that the fan may either drive or draw a current of air over the armature.

Also relates to the winding of armatures with parallel wires.

Also of inserting a sensible resistance between the sections of the armature and the commutator.

1884. S. WILLIAMS. **11542.**

Improvements in Dynamo-Electric Machines.

Relates to improvements to machine in Patent No. 314, 1884, and describes the manufacture of the conductors of armature of straight flat bars joined at each end.

1884. HON. C. A. PARSONS. **14723.**

Improvements in Dynamo-Electric Machines.

Describes the construction of a generator with an armature of Siemens type, the core or drum being formed of iron plates fitted to the shaft; these

plates are insulated from each other; equi-distant longitudinal channels are formed on the core, in which the conductors are placed. Also describes method of regulating speed of dynamos.

1885. A. L. DAVIS. 3332.

An Improved Ventilating Armature for Dynamo-Electric Machines.

Describes the construction of the H iron core of Siemens' armature, and consists of a number of stamped plates bolted together.

IV.—OF THE LONTIN TYPE.

1882. A. L. FYFE and J. MAIN. 2636.

Improvements in and connected with Dynamo-Electric, Magneto-Electric, and Electro-Magnetic Machines, also applicable as Electro-Motors.

Armature consists of a number of coils arranged parallel to axle of machine; these coils have plates of iron at each end radiating from centre. Four or more polar extensions of field electro-magnets are placed on each side of the armature.

1882. F. C. GLASER. 4535.

(From C. ZIPERNOWSKY and M. DERI.)

Improvements in Dynamo-Electric Machines.

Describes an iron cylinder with zigzag-shaped pieces projecting inwardly and forming cores on which wire is wound; this is called the induction cylinder, being that in which the alternating currents are produced; within this cylinder revolve electro-magnets which radiate from the shaft of the machine, the polar extremities of these electro-magnets being close to the inside poles of coils of the cylinder.

1882. H. MAYHEW. 5304.

Improvements in Machinery or Apparatus for Producing Dynamo- and Magneto-Electricity by a Self-sustaining and Self-rotating Process.

Describes a combination of machines, one of which the inventor calls the exciter, another rotator, and the multiplier. The generator proper consists of thirty-six coils ranged radially along the circumference of a central cylinder so that they may constitute half a dozen concentric rings, containing six of such electro-magnets in each of such rings; these are made to revolve between the poles of a rectangular horse-shoe magnet having broad flattened branches or limbs.

1884. J. H. GREENHILL. 3571.

Improvements in Dynamo-Electric Machines.

Relates to the construction of an armature with the coils arranged radially

from the shaft. The iron cores are made ring shape from sheet iron, with projecting pieces on the outer edge; several of these rings are fitted together, and the coils placed on the projections.

V.—MISCELLANEOUS.

1882. H. E. NEWTON. 1211.

(From A. G. Gravier.)

Improved Machinery for Obtaining Electric Currents.

A ring of sheet iron or iron wire is wound with a series of coils of wire, similar to a Gramme ring; the wires from these coils are led to a commutator.

Around these coils another series of coils are wound, the ends of which are led to a commutator on the opposite side of the machine.

The system of two sets of coils are made to revolve.

When currents are passed through one set of coils by means of the commutator, a current is set up in the other set of coils, and collected by means of its commutator.

1882. T. J. HANDFORD. 1496

(From T. A. Edison.)

Improvements relating to Dynamo- or Magneto-Electric Machines, for Regulating the Generative Capacity of such Machines.

Uses a rapidly vibrating circuit controller automatically operated by the current generated, and serving to control and regulate the energy of the field magnet by successively opening and closing a circuit.

1882. B. H. ANTILL. 1787.

Improvements in Dynamo-Electric and Electro-Dynamic Machines.—(Void through non-filing of Specification.)

Describes machines in which electric currents are generated in coils of wire by the movement of the coils through magnetic fields without change of polarity or by movements of magnetic fields of constant polarity relatively to the coils of wire.

1882. J. H. JOHNSON. 1878.

(From J. M. A. Gérard-Lescuyer.)

Improvements in Dynamo-Electric Machines.

Describes an iron disc wound with two coils of wire, one on each side embracing upper part of the disc, and the other coil embracing the lower portion. The disc carrying the coils is fitted to the spindle; eight projections are fitted on the disc, four on each side; these approach close to the poles of the field electro-magnets when the disc is revolved.

1882. T. J. HANDFORD. **2052.**

(From T. A. Edison.)

Improvements in Electrical Generators and Engines, and in Apparatus or Means for Regulating Generators of Electricity.

Employs an armature composed wholly or principally of metal discs connected in such a manner that the machine will develop a continuous current having a tension due to the E.M.F. of number of discs connected.

Employs also field electro-magnets having bevelled polar extensions enclosing the armature.

1882. T. FLOYD and T. KIRKLAND, Jun. **2225.**

An Improved Dynamo-Electric Machine.—(Provisional.)

Proposes to revolve both the field electro-magnets, also the armature, in opposite directions.

1882. J. M. STUART. **2232.**

Improvements in Apparatus for Generating Electric Currents.

Employs concentric cylinders wound with wire forming armatures. The cylinders are revolved in reverse directions within polar extremities of field electro-magnets.

1882. B. H. CHAMEROY. **2295.**

Improvements in or relating to Compensating Dynamo-Electric Machines.

Armature coils are arranged in the form of a spiral round the spindle; extended poles of the field electro-magnets surround the armature, and are arranged with an adjustment by means of a set screw.

1882. A. J. JARMAN. **2630.**

Improvements in Dynamo-Electric Machines.

The pole-pieces of field electro-magnets are made to advance or recede from each other and from the armature they enclose, in order to regulate the current derivable from dynamos.

1882. J. IMRAY. **2769.**

(From P. Jablochkoff.)

Improvements in Dynamo-Electric and Electro-Dynamic Machines.

Describes improvements consisting of a magnetic coiled bobbin fixed obliquely on an axis, and revolving between or within polar fields, so as to present opposite edges to opposite fields alternately.

1882. C. E. KELWAY. **2910.**

Improvements in Machinery or Apparatus for Generating and Utilising Electricity. (Provisional.)

Describes machine in which armature is revolved in opposite direction to eld magnets.

1882. P. JENSEN. **3002.**

(From D. A. Schuyler and F. G. Waterhouse.)

Improvements in Dynamo-Electric Machines.

Describes armature with four separate coils arranged on an annular core, and placed between two poles of field magnets.

Another form of machine is described where the armature coils are fixed and the iron core is revolved. Polar extremities of field electro-magnets arranged between the fixed armature coils in such a manner that polar extremities of the iron core of the armature are arranged to pass the armature coils at same time as it passes the poles of field magnets.

1882. T. VARLEY and H. B. GREENWOOD. **3129.**

Improvements in Machines for Generating Electricity.—(Provisional.)

The object of this invention is to dispense with the use of a commutator. Through one pole of a magnet a hole is formed, through which is a revolving tube; inside this tube an iron bar is placed, the end of which is joined to the opposite pole of the field magnet; when the tube is revolved it has a constant electrical current passing through same from end to end.

1882. R. WERDERMAN. **3150.**

Improvements in Dynamo- or Magneto-Electric Machines which will also serve as Electro-Motors.

Describes a framework in which is arranged a number of pairs of poles; between each pair an armature is made to revolve.

1882. W. R. LAKE. **3160.**

(From J. Carpentier.)

An Improved Method and Means for Regulating the Current in Dynamo-Electric Machines.—(Provisional.)

Describes a method of graduation of an induced current by periodical interruptions. An electro-magnet wound with fine wire is interposed in the circuit of the wire of the field electro-magnets and an exciting machine; the armature of the electro-magnet, being attracted by an excess of current, establishes a direct communication between the poles of the exciting machine, and instantaneously suppresses the inducing current.

1882. S. Z. DE FERRANTI and A. THOMPSON. **3419.**

Improvements in Dynamo-Electric Machines or Electric Generators.

The armature is constructed with the coils arranged around the periphery of a wheel, and consists of one single conductor passing in an undulating form around the wheel, first outwards from the centre of the wheel between two adjacent poles of the fixed magnets, then returning inwards towards the centre between one of these poles and the pole of a third magnet, and so on until the circuit is complete. Wire may be wound in the same manner. No iron core or pole-pieces are used.

1882. J. S. BEEMAN. **3455.**

Improvements in Dynamo- and Magneto-Electric Machinery.

Relates to the removing automatically from the armature certain portions of the circuit, and automatically replacing them by insulated stops or contact-pieces with metallic rubbing surfaces, so that the surfaces connect and complete the circuits.

1882. C. A. CARUS WILSON. **3466.**

Improvements in the Means or Apparatus for Generating Electric Currents and Producing Motion by Electricity, and for Regulating Electric Currents and Making and Breaking Circuits.—(Provisional.)

A circular solenoid consisting of a number of flat metal washers insulated from each other and each having a slot cut radially; these washers are connected by wires, so that when a current is introduced into one it travels round it, and then along a wire at the other side of the ring, back to the first side, and through a second washer, and so on.

1882. A. D'ORELI. **3504.**

A New or Improved Machine for Generating Electricity.—(Provisional.)

Employs an armature plate pierced through with holes corresponding to two series of fixed bobbins composed of magnets wound with wire. This armature disc is carried on a shaft, and also carries on the faces soft iron pole-pieces. The pierced armature disc by its motion transfers the current alternatively upon each opposite bobbin of the fixed series, and also transfers the current to the commutator.

1882. O. W. F. HILL. **3534.**

Improvements in Dynamo-Electric Machines or Electric Generators and Electro-Motors.

A series of coiled armatures are made to roll upon magnetised rings, each armature in succession coming in contact with the rings and separating from them.

1882. L. CAMPBELL. **3582.**

Improved Means of Regulating Electric Currents and Electro-motive Force, and Apparatus therefor.—(Provisional.)

Relates especially to the construction, arrangement, and automatic application of the commutator brushes in order to take advantage of the variation of the electric potential in the different parts of the commutator.

1882. J. IMRAY. **3591.**

Improvements in Electric Producer and Power Machines.

The armature, also the field electro-magnets, consist of two iron sheets or flanges coiled with insulated wire in convolutions parallel to their surfaces, and having alternate polar extensions projecting from their ends or edges.

1882. S. Z. DE FERRANTI and A. THOMPSON. **3950.**

Improvements in Dynamo-Electric Machines or Electric Generators and Apparatus connected therewith.

Describes an armature for producing continuous currents, made up in a zig-zag conductor composed partly of radial conducting bars in a magnetic field, and partly of contact bars for making the required contacts between the outer and inner ends of the bars.

1882. J. E. T. WOODS. **3974.**

Improvements in Dynamo-Electric Power-creating Machines.—(Provisional.)

Describes the use of iron wires for cores of electro-magnets in dynamos, also the use of square wire for winding the coils.

1882. T. DONNITHORNE. **4250.**

Improvements in Dynamo-Magnetic Electric Machines, and in Magnets to be used in such Machines, and for other purposes.

Relates chiefly to magnets which are made of a tube of soft iron filled with magnetic iron ore.

Describes also a form of dynamo, but it is not described clearly.

1882. J. W. SWAN. **4461.**

Improvements in Dynamo-Electric and Magneto-Electric Machines.—(Provisional.)

Armature consists of a flat spiral ring of copper, whose diameter greatly exceeds its thickness, and in which are cut radial slots extending alternately from the exterior and interior of the ring part way across its width; it is rotated between the poles of magnets or electro-magnets arranged on each side in a circular form.

1882. R. BARKER. **4547.**

Improvements in Dynamo-Electric Machines.

Relates to the construction of the field magnets and framework so as to allow of an opening for removing the armature without taking the machine to pieces.

Also describes the bevelling of the polar extremities of field magnets to give greater intensity to the field. They are also formed with a serrated edge.

1882. J. S. BEEMAN, W. TAYLOR, and F. KING. **4680.**

Improvements in Dynamo-Electric and Magneto-Electric Machines.

(Void. Specification not filed.)

The field magnets revolve in an opposite direction to the armature.

1882. E. EDWARDS, A. F. ST. GEORGE, and H. L. PHILLIPS. **4694.**

Improvements in Machinery or Apparatus for Generating and Utilising Electricity.

Relates to the construction of the armatures or field magnets of helical form.

1882. J. GORDON and J. GRAY. **4717.**

Improvements in Disc Dynamo- and Magneto-Electric Machines and Electro-Motors.

Thin discs of conducting material rotate between the poles of a magnet, and are divided or built up in radial sections, and rolling in contact or connected by brushes.

1882. R. KENNEDY. **4752.**

See Incandescent—Miscellaneous.

1882. A. C. ELLIOTT. **4928.**

An Improved Dynamo-Electric Machine.—(Provisional.)

Armature is built up of segments of iron so as to form a cylinder between these segments. Round the middle of the armature is wound a stationary coil of wire, which is used to create a magnetic field and influence the coils of the armature.

1882. F. H. VARLEY. **5055.**

Improvements in Generating and Storing Electricity, and in Appliances connected therewith.

An armature is constructed with iron spokes or cores radiating from the shaft, with angular ends on which the coils are placed; the armature rotates between four polar extensions of field magnets.

Also describes a machine where an alternating or reciprocating motion is imparted to the armature.

Also describes use of galvanised iron and zinc plates, in conjunction with prepared carbon, for electrodes for storage batteries; also silicium and boron in conjunction with fibrous material.

1882. J. S. FAIRFAX. **5060.**

Improvements in Machines and Apparatus employed in the Production, Collection, and Utilisation of Electric Currents or Forces.

Relates to the construction of armatures where iron or steel dust is used to construct the magnets. Various armatures are described in which the above is carried into effect.

1882. S. P. THOMPSON. **5122.**

Improvements in Electric Current Generators and Motors.

Relates to the combination of armatures in the form of copper discs, the use of double discs with external concentrically arranged field magnets or pole-pieces, the polarity of such external pole-pieces being alike on both sides of the armature, and contrary to that developed between or within the discs.

1882. B. J. B. MILLS. 5148.

(From T. CHUTAUX.)

Improvements in the Organs of Dynamo-Magneto or Electro-motive Machines, and in other Electrical Apparatus in the Construction of which Iron, Cast Iron, Steel, or other Metals, are used.—(Provisional.)

Relates to the construction of iron cores with grooved or slotted edges or poles, so that these poles may move between similar slotted poles in the field electro-magnets.

1882. J. D. F. ANDREWS. 5158.

Improvements in Apparatus for Producing and Regulating Electricity.

Employs an armature constructed with parallel copper bars connected in series, and having their junctions connected with the plates of the commutator. Two sets of commutators are used in this machine.

1882. C. D. ABEL. 5594.

(From B. ABDANK-ABAKANOWICZ and C. ROOSEVELT.)

Improvements in Dynamo-Electric Machines.

Employs conductors of flat wire or ribbon in a zigzag form for coiling round the core by folding. Also describes the form and shape of the pole-pieces of field magnets.

1882. G. L. ANDERS and J. B. HENCK, JUN. 5961.

Improvements in Dynamo or Magneto-Electric Machines.

A globular shell of copper arranged to revolve about an axis coinciding with the magnetic axis of the permanent or electro-magnetic system, by which the field is maintained within the shell.

Another form of machine is described where there is an inner and outer shell of iron, the inner shell being made to revolve, while the outer shell is fixed.

Also describes a machine with electro-magnet coils provided with solid iron poles placed end to end, forming a ring; these are made to revolve between field electro-magnets constructed in a similar manner, but with the poles of the coils bent inwards so as to come in close proximity to each side of the armature coils.

1882. T. J. HANDFORD. 6183.

(From T. A. EDISON.)

Improvements in Electrical Generators and Motors.

Describes the construction of an electrically divided current collector, used for taking the current from the commutator of the armature.

1883. S. Z. DE FERRANTI. 36.

Improvements in Apparatus for the Generation and Utilisation of Electric Currents.
(Provisional.)

Causes a conductor in which an alternating current passes to approach towards and recede from another conductor, and the movements are synchronised with the pulsations of the alternating current, so that during both advance and retreat induction operates in one and the same direction, and hence gives rise to a current always flowing in one direction.

1883. H. F. JOEL. 120.

Improvements in Magneto-Electric Machines.—(Provisional.)

Radial copper bars connected together form the armature, and pass through successive fields of magnetism.

1883. H. H. LAKE. 357.
(From H. R. BOISSIER.)

Improvements in Dynamo- or Magneto-Electric Machines.

Relates to construction of collectors or brushes of a dynamo machine, and the holders for same.

1883. W. M. MORDEY. 400.

Improvements in Electric Generators and Motors.

Relates to the arranging and connecting the ends of the wires from the armature coils to the commutator or terminals so that all the coils are connected which are in a state of equal potential.

1883. S. PITT. 535.
(From F. B. CROCKER, C. G. CURTIS, and S. S. WHEELER.)

Improvements in Electro-Motors and Dynamo-Electric Machines.

Relates to the winding of field electro-magnets with two separate conductors. One set of their free ends are connected together, and one to the current-supplying conductors, and the other to a circuit-controlling switch, whereby one, two, or more of the field magnet or armature conductors may be connected to the other circuit-supplying conductor in multiple arc.

1883. R. W. MUNRO. 628.
(From A. E. SWONNIKOFF.)

An Improved Dynamo-Electric or Electro-Dynamic Machine.—(Provisional.)

Relates to the placing of the poles which face the armature coils at such an angle that the armature in passing them undergoes a gradual, and not a sudden, change of influence.

1883. J. MUNRO. 661.

Improvements in Dynamo-Electric Machines.

Describes armatures constructed with grids of copper or other suitable strips or bars, and placed on the sides of a rotating disc, either radially or in fan-like sections.

Describes also an armature constructed or one or many grids of longitudinal bars of copper arranged upon the circumference of a rotating drum frame.

1883. F. M. NEWTON. 867.

Improvements in Apparatus for Generating and Utilising Electricity.

Relates to machine in which the field magnets revolve and the armature is fixed. The field magnets consist of coils which radiate from the shaft, and the whole are surrounded by an iron drum on which the armature coils are wound. The wire is wound in such a manner as to present six equi-distant strands along the interior surface of the drum, parallel to its axis.

Describes also an arc lamp in which the electrodes pass through a guide or tube of refractory material. A projection or lip at the end of the tube prevents the passage of the carbons beyond that point.

1883 C. LEVER. 1198.

Improvements in Dynamo-Electric Machines.

Describes the application of a polarised revolving inductor, magnetically connected to its paramagnetic spindle, which revolves in one or more pole pieces of the field magnet, the inductor rotating before, between, or within the armature coils, whereby alternate currents are generated and distributed without the use of a commutator or collector. Both the armature and field magnet are fixed.

1883. H. H. LAKE. 1313.
(From G. W. FULLER.)

Improvements in Dynamo-Electric Machines.

Relates to the construction of an alternating current machine consisting of three systems of field magnets supported respectively in three circles upon the interior of a rotating shell, and forming a series of radially arranged groups, each composed of three magnets, the three magnets of each group being of like polarity to each other, but of opposite polarity to the adjoining groups, and presenting their poles in close proximity to and parallel with the three sides respectively of triangular coils transversely surrounding an endless bar or annular core.

1883. C. W. VINCENT. 1314.

Improvements in Dynamo and Magneto-Electric Machines.

Relates to making the core of armature coils of iron or steel filings. Also relates to winding the coils of the armature and field magnets with insulated iron or steel wire.

1883. H. H. LAKE. **1347.**

(From G. W. FULLER.)

Improvements in Dynamo-Electric Machines.

Improvements to Patent 1313, 1883.

The field magnets rotate and the armature is fixed. The armature is constructed with two long segments of iron secured to two short segments of non-magnetic material, and the two circles of rotating field magnets; the magnets of like polarity adjoin each other, and are united by common pole-pieces; those of the field magnets which are of one polarity being upon one side of the axis of the machine, and those of the other polarity being upon the other side. The armature coils are arranged between the segments of iron referred to.

1883. C. W. SIEMENS. **1364.**

Improvements in Dynamo-Electric and Electro-Dynamic Machines, and in Appliances connected therewith for Measurement of Electric Power.—(Provisional.)

Relates to starting of induction currents in dynamo machines either by transmission of a current from an extraneous source or by the presence of a permanent magnet.

1883. H. H. LAKE. **1375.**

(From G. W. FULLER.)

Improvements in Dynamo-Electric Machines.

Describes armature constructed of a system of induction bars arranged in the form of a cylindrical cage and loosely surrounding a stationary cylindrical iron core. One pole of field magnets embraces one half of the armature, and the other pole of the field magnets the other half.

1883. J. B. ROGERS and H. O. CONNOR. **1518.**

An Improved Manufacture or Construction of Armatures for Dynamo-Electric Machines.—(Provisional.)

Relates to the construction of the cores of coils for dynamos of small pieces of iron mixed or laid up in plaster of Paris, or other suitable substance, so as to make a solid mass.

1883. S. P. THOMPSON. **1639.**

Improvements in Dynamo-Electric Machinery, and in Apparatus for use in connection therewith or for other purposes.

Relates to machine with armature coils and field-magnet coils fixed; opposite the ends of these coils inductors or iron plates are made to rotate.

1883. T. WIESENDANGER. **1759.**

Improvements in Apparatus for the Production and Regulation of the Electric Light and Power, viz., Dynamo Machines and Regulator Arc Lamps.—(Provisional.)

The description of the apparatus in this patent is not clear, but refers to a

machine with coils wound on projections on a disc; it also refers to an arc lamp regulated by a wheel train.

1883. P. M. JUSTICE. 1803.
(From — KEEGAN.)

Improvements in Dynamo-Electric Machines, the Invention being also applicable to Electric Motors.—(Provisional.)

The object aimed at in this invention is to reduce the amount of power required to work a dynamo by changing the polarity of the instant poles at time of motion without any disruptive discharge. Relates also to avoiding the production of secondary induced currents in the wire coil of the induced magnet and inducing magnet.

1883. SIR WM. THOMSON. 2028.

Improvements in Apparatus and Processes for Generating, Regulating, and Measuring Electric Currents.

Describes dynamo with armature constructed of radial bars of copper, disposed like the spokes of a wheel about an axis which may be either horizontal or vertical. These radial bars are metallically connected at their outer ends by a copper band or other suitable connection forming the periphery of the wheel, and throughout their length they are insulated from each other, their inner ends being metallically connected each to commutator bars. The current is induced by the motion across the lines of force placed approximately perpendicular to the plane in which the radial bars of the armature move.

Also describes a potential regulator and current meter.

1883. G. HOOKHAM. 2042.

Improvements in Magneto-Electric Machines, parts of which are also applicable to Dynamo-Electric Machines and Electro-Motors.

Employs permanent inducing magnets, which rotate, while the armatures in coils on which electric currents are induced are stationary.

1883. H. ROBERTS. 2064.

Improvements in Means and Apparatus for Preventing Excessive Heat in Dynamo-Electric Machines.

Describes a blowing machine with blast nozzles arranged for directing currents of air upon the parts which are likely to be heated.

1883. SIR C. T. BRIGHT. 2280.

Improvements in Dynamo-Electric Machines and Electro-Motors.

Describes armature coils fixed and wound on an annular non-magnetic core, or may be electro-magnets. The field electro-magnets are wound on fixed hollow cores through which passes an iron or steel shaft which is divided by a non-magnetic metal between the coils, and the divided ends of the shaft, also

made of iron or steel, are extended in the form of segments of a circle or radial arms, but on opposite sides to one another. In immediate proximity to the outer parts of the segments the circular series of armature coils are arranged.

1883. E. L. VOICE. **2434.**

New or Improved Means or Apparatus for Producing, Distributing, and Utilising Electricity for Lighting, Motive Power, and other purposes.

Relates to the utilisation of the induced currents caused by the periodical cessation or reversal of magnetic polarity in electric machines.

1883. T. T. VERNON. **2553.**

Improvements in Dynamo-Electric Machines and Electro-Motors.—(Provisional.)

Uses as small a quantity as possible of metal in dynamos, and constructs framework of machines of a non-conducting material, and the field magnets without iron cores.

1883. W. STROUDLEY and J. HOUGHTON. **2579.**

See Lighting Railway Trains, &c.

1883. W. HOCHHAUSEN. **2670.**

Improvements in Dynamo-Electric Machines.

Armature constructed of discs of metal cut into a series of zigzag forms. The portions of the discs in which the currents are set up are radial. A number of these plates are placed together with insulating material between them. In some cases the field magnets are at opposite sides of the armature discs, and in other instances the armature discs are at a sufficient distance from each other to allow for the field-magnet poles to be introduced between them.

1883. W. H. SCOTT. **2763.**

Improvements in Apparatus for Generating, Distributing, Regulating, and Measuring Electricity; applicable for the purposes of Illumination, and for the Conversion of Electricity into Motive Power.—(Provisional.)

Describes armature constructed of a cylindrical drum having a number of longitudinal slots in which the wire is wound. The field magnets are constructed in a similar manner, and surround the armature.

1883. A. GRAY and T. GRAY. **2804.**

Improvements in Apparatus for Generating, Regulating, and Distributing Electric Currents and Electric Energy.

Describes armature constructed of bars or strips placed raidally in zigzag form, and rotating between pole-pieces.

Also describes armature constructed of a series of strips so as to form a hollow drum or cylinder, shaped as if it were composed of alternate portions of two cylinders of different diameters. The armature thus made rotates so

that the cylindrical portions of smaller diameter pass under the field magnets, and the outside bars round the outside of the magnets.

Also relates to arc lamp in which the regulation is effected by means of a small motor which controls the rod through gearing.

1883. W. R. LAKE. 2856.

(From M. BOLLMANN.)

Improvements in Electrical Generators and Motors.—(Provisional.)

Relates to apparatus in which secondary currents are produced but are not commutated and carried off for use, but only used for exciting in the conductor of the inducing main current induction currents of the second order (tertiary currents), of the same direction as the main current, which is thereby strengthened.

1883. M. DEPREZ. 3074.

Improvements in Dynamo-Electric Machines.

Describes the construction of dynamo-electric machines in such a manner that the slow and progressive magnetisation of the electro-magnets, and the reversal likewise of the poles, either of the inductor or induced body, are produced by means of a sectional winding of the wire.

1883. PROFESSOR G. FORBES. 3115.

Improvements in Dynamo-Electric Machines.

The armature is a revolving mass of iron, without coils, and the field magnets are continuous all around the armature, which they completely enclose, except that there is a central hole by which the axis passes. The magnet presents a continuous north pole to one side and a continuous south pole to the other side of the armature, whose polarity is also continuous.

1883. L. F. LAMKIN. 3223.

Improvements in and applicable to Dynamo-Electric, Magneto-Electric, and similar Machines.

Relates to controlling the electro-motive force of the current generated by varying the relative position of the brushes on the commutator.

1883. W. S. FROST. 3457.

Improvements in Electric Machines.—(Provisional.)

Relates to the production of a continuous current from dynamos by driving same by accumulators, and without the use of steam or other prime mover.

1883. S. Z. DE FERRANTI and A. THOMPSON. 3702.

Improvements in Dynamo-Electric Machines or Electric Generators.

Relates chiefly to improvements to Patent 3419, 1882.

1883. W. P. THOMPSON. **3934.**
(From R. J. SHEEHY.)

Improvements in Dynamo-Electric Machines.

Relates to the construction of machines with an armature plate or disc of iron, having projections on both sides, between which two series of bobbins are placed, one on either side, the bobbins of one series being placed in intermediate angular positions to those of the other series.

1883. W. P. THOMPSON. **4578.**
(From R. J. SHEEHY.)

Improvements in Dynamo-Electric Machines.

Relates to the combination of a number of field pole-pieces arranged in a series of alternating polarities, and provided with intermediate armatures between adjacent pole-pieces, and exterior armatures against the outer faces of exterior pole-pieces.

1883. F. H. VARLEY and J. R. SHEARER. **4594.**

Improvements in Dynamo-Electric Machines.

Describes the construction of a machine with a fixed magnetic core, surrounded by a cylindrical magnetic sheet sufficiently large to leave an annular space in which a cylindrical cage, made of bar conductors placed parallel to each other and to the axis of the magnetic cylinder, may rotate freely.

1883. H. B. FORD. **4780.**

Improvements in and Additions to Dynamo- or Magneto-Electric Generators.
(Provisional.)

Relates to the arranging of a means of compressing air, gas, vapour, or steam in the working of a dynamo so that the power so stored shall be given out in assisting to work such machine.

1883. T. J. HANDFORD. **5127.**
(From T. A. EDISON.)

Improvements in Electrical Generators and Motors.

Relates to a method of overcoming, wholly or partially, the sparking at the commutator.

1883. S. Z. DE FERRANTI. **5132.**

Improvements in Dynamo-Electric Machines.

Relates to method of winding field magnets by winding the coils parallel to the axis of the armature and passing alternately over and under it.

1883. J. S. FAIRFAX. **5272.**

Improvements in Machines and Apparatus employed in the Production, Regulation, and Utilisation of Electric and Magnetic Forces.

Relates to various methods of arranging the wires and winding coils of dynamo machines.

1883. G. HOOKHAM. **5408.**

Improvements in Magneto-Electric and Dynamo-Electric Machines.—(Provisional.)

Improvements to Patent No. 2042, 1882.

Instead of employing only one series of permanent U-shaped magnets radially on a rotating shaft, two series are employed at a short distance apart. The arms or poles of each magnet of one series are opposite to arms or poles of different polarity on the other series.

1883. SIR C. T. BRIGHT. **5422.**

Improvements in Dynamo-Electric Machines and Electro-Motors.

Improvements to Patent No. 2280, 1883.

Relates to the further application of the system to machines producing alternating currents, in which the moving part is confined to the metallic shaft and its extensions, and in which the employment of collectors or commutators is unnecessary.

1883. E. C. WARBURTON and L. J. CROSSLEY. **5865.**

Improvements in Dynamo-Electric Machines.

Relates to the construction of dynamos in which a rotary motion is given to the field magnets, as well as to the armatures, in directions opposite to each other.

1883. A. M. CLARK. **5881.**

(From H. M. PAINE.)

Improvements in the Method of and in Machines for Producing Electric Currents. (Provisional.)

Describes arrangements by which the armatures, when passing through the field of force, during open circuit, are charged with static electricity, and when the neutral axes of the field magnets and armatures are coincident, the circuit is closed and dynamic electricity is discharged through the commutator.

1883. A. DE MEURON and H. CUENOD. **5682.**

Improvements in Magneto- and Dynamo-Electric Machines with Continuous Currents.

The armature is constructed with a drum, which may be magnetic or not, covered with wires placed longitudinally and parallel to the axis; the extremities of these wires are connected, each forming a chord of the

circumference of the base of the drum, and each of them measuring a fourth, or sixth, or even number, of parts of the circumference; the polar extremities of the field magnets surround the armature, their number being made proportional to the winding of the armature.

1883. S. Z. DE FERRANTI. **5926.**

Improvements in Dynamo-Electric Machines and Electric Meters.

Describes the construction of a dynamo-electric machine by which a continuous current may be produced without the use of a commutator, and consists of an armature constructed of a disc of copper, which revolves between two annular poles of field magnets.

1884. SIR C. T. BRIGHT. **231.**

Improvements in Dynamo-Electric Machines and Electro-Motors.—(Provisional.)

Relates to machines having fixed field-magnet coils opposite to each other in polarity, combined with movable induced pole-pieces of iron.

1884. W. M. MORDEY. **262**

Improvements in Dynamo-Electric Machines.—(Provisional.)

Relates to the construction of an armature of an undulated or wavy form externally, and of the field magnets, whose pole-pieces present to the armature similar undulatory or wavy faces, so that the polar surfaces are parallel to the surfaces of the armature.

1884. E. B. BRIGHT. **2041.**

Improvements in Dynamo-Electric and Electro-Motive Machines.

Describes the construction of field magnets with pole-pieces so arranged as to produce a continuous field in a rotating armature.

1884. A. N. THORIN. **4651.**

Improvements in Dynamo-Electric and Magneto-Electric Machines.

Employs an armature constructed of a number of coils of insulated wire wound in the form of a ring, which coils are placed more or less one upon another.

1884. W. H. SCOTT and E. A. PARIS. **4683.**

Improvements in Dynamo-Electric Machines.—(Provisional.)

Describes the construction of an armature in the form of a hollow cylinder or drum, having its circumference made of paper surrounding the iron core, which is carried on a fixed central spindle; the wire is wound longitudinally on the drum; the ends of the coils form chords of an arc of the circle of the drum.

1884. W. H. SCOTT and E. A. PARIS. 6260.

A New or Improved Method of Electrical Distribution.

Relates to the construction of machines called "transformers," and which consist of an armature wound with two sets of conductors, one set for high-tension current, and the other set for low-tension; and relates also to the arrangement of the transformers, both in high-tension and low-tension circuit, in parallel, so as to be independent of one another.

1884. G. HOOKHAM. 7533.

Improvements in Dynamo-Electric Machines and Electric Motors.

Describes the use of a ribbed or slotted armature core, so proportioned that the sum of the magnetic sections of the ribs or ridges shall equal the magnetic section of the solid core.

1884. G. G. M. HARDINGHAM. 7805.

(From C. M. STERLING.)

Improvements in Machines for Generating or Utilising Electrical Energy.

(Provisional.)

Describes the use of circular permanent magnets revolving within fixed induction coils in such a manner that the windings of the coils are arranged to enclose the magnets. Also relates to using revolving electro-magnets in place of permanent magnets.

1884. A. SPÖREL. 9409.

Improvements in Dynamo-Electric Machines.—(Provisional.)

Relates to a machine constructed to utilise the Foucault currents generated in a copper disc when turned in front of the poles of a magnet, the disc in this machine being constructed with two flat copper spirals.

1884. A. M. CLARK. 10323.

(From E. B. CUTTEN.)

Improvements in Dynamo-Electric Machines.

Relates to the construction of field magnets, with the electro-magnet arms having the inner side perpendicular and the outer inclined.

1884. T. J. HANDFORD. 10474.

(From R. H. MATHER.)

Improvements in and relating to the Ring Magnet of Dynamo-Electric Machines.

Describes the construction of field magnets in the form of a ring, and the winding of same with a cable composed of a series of insulated wires having their ends connected together for forming one continuous wire.

1884. PROF. G. FORBES. **11244.**

Improvements in Dynamo-Electric Machines.

Relates to improvements to Patent No. 3115, 1883, in the construction of armatures for dynamo-electric machine.

1884. G. SCARLETT. **13162.**

Improvements in Electro-Dynamic or Dynamo-Electric Machines.

Relates to the construction of a machine with a revolving magnetic ring or core separated at intervals by insulating material and surrounded by a series of stationary coils.

1884. W. R. LAKE. **14779.**
(From L. BOLLMAN.)

Improvements in Dynamo-Electric Machines.

Describes the non-employment of iron in the rotating armature, and the construction of an armature with radial strips of copper, connected by other strips running in circular directions, to form circuits for the current to circulate many times in opposite directions through the strips.

1884. S. PITT. **14916.**
(From C. DE NOTTBECK.)

Improvements in Dynamo-Electric Machines.

Relates to the construction of commutators or collectors.

1884. H. CUSHMAN and J. P. HALL. **16417.**

Improvements in Electric Generators and Motors.

Relates to the construction of an armature wound in such a manner that at intervals the conductor takes a radial direction with respect to the boss of the armature, and mounted with respect to the field magnets that the radial portions of the conductor cut the lines of force at right angles.

1884. H. F. JOEL. **17091.**

Improvements in Magnetic Electric Machines.

Relates to the construction of laminated magnet cores fitted into solid pole-pieces, or laminated pole-pieces fitted into solid cores.

1885. A. F. LINK. **2671.**
(From A. G. HELIOS.)

Improvements in Dynamo Machines.

Relates to the use of insulated iron wire for armature. Also describes use of poles of field magnets having a number of channels or recesses for the reception of an equal number of revolving armatures.

1885. W. H. ALLEN, R. WRIGHT, and G. KAPP. 2776.

Improvements in Dynamo-Electric Machines, Magneto-Electric Machines, and Electro-Motors.

Describes various methods of construction of iron annular cores of plates or iron wire.

1885. G. HOOKHAM. 3212.

Improvements in Dynamo-Electric Machines and Electro-Motors.

Describes the construction of iron cylindrical cores having longitudinal slots around their circumference for receiving the wire; also describes several methods of winding wire on same.

1885. T. J. HANDFORD. 3446.

(From F. J. SPRAGUE.)

Improvements in and relating to Electrical Generators and Motors.

Describes method of winding wire of dynamo machines so that the number of turns in the shunt coil bears the same relation to the number in the series coil as the resistance of the shunt coil bears to the sum of the resistances of the series coil and the armature.

1885. T. J. HANDFORD. 3524.

(From F. J. SPRAGUE.)

Improvements in and relating to Electro-Dynamic Motors, parts of which Improvements are also applicable to the Regulation of Dynamo-Electric Generators.

Describes dynamo having field magnets independent of the armature circuit, and variable, shunted upon the main field-coils, whereby the magnetising effect of independent coils is varied or reversed.

1885. R. P. SELLON and J. S. SELLON. 3525.

Improvements in Apparatus for Distributing and Utilising Electricity.

Describes the winding of an annular core with two distinct and independent sets of coils, whereby a current of high tension may readily and simply be converted into one of low tension.

1885. A. RECKENZAUN. 3599.

Improvements in Electro-Motors or Dynamo-Electric Machines.

Describes construction of permanent field magnets of a number of horseshoe laminæ or plates without yoke-pieces, and connected by segmental pole-plates.

1885. T. J. HANDFORD. **8566**

(From R. H. Mather.)

Improvements in or relating to Dynamo-Electric Machines, for Preventing Sparking in such Machines.

Describes a spark-preventing device, consisting of an electro-magnet whose helix is located in the main circuit of the machine, and so placed that the neutral point or points of the armature of such machine shall be within the magnetic field of this electro-magnet.

SUBDIVISION II.

LAMPS.

ARC.

I.—VERTICAL CARBONS.

1882. R. KENNEDY. **1199.**

A New or Improved Electric Lamp of the Arc type.

In this lamp both carbons are movable, the upper one being held by a clamp fixed to a hollow iron core surrounded by a coil of fine wire; the iron core with the fine wire wound round it, moves inside a thick wire solenoid; the weight of the upper core and carbon raises the lower carbon by means of pulleys and cords.

1882. J. D. F. ANDREWS. **1324.**

Improvements in Electric Lamps.

Describes lamp having upper carbon-holder attached to a tube forming one of the guides; inside this tube is a piston which allows the tube with its holder to descend gently, the regulation of the fall of the tube being effected by means of a clutch, which is actuated by the core of a solenoid separating the bottom carbon from the top when the lamp is started.

Describes also a number of carbon rods  arranged side by side. The upper set are regulated by a conical roller, and the bottom set press against shoulders provided for same, the carbons being raised by spiral springs.

An incandescent lamp is described in which, instead of employing a fibre, a thin plate of carbon is used, having its edges clamped between the limbs of a bent platinum wire.

1882. W. JEFFERY. 1570.

Improvements in Electric Arc Lamps.

The upper carbon is attached to a rod which passes through a loop or ring acting as a clutch; the ring is moved by the armature of an electro-magnet. The bottom carbon is fixed.

1882. W. R. LAKE. 1611.

(From E. WESTON.)

Improvements in Electro-Magnetic and Regulating Apparatus, chiefly designed for use in Electric Lamps.—(Provisional.)

Describes the use of solenoid with iron core to actuate the clockwork regulating the movement of the upper carbon.

1882. J. MUNRO. 1626.

See Miscellaneous—Various.

1882. G. S. YOUNG and R. J. HATTON. 1689.

Improvements in Electric Lamps.

In this lamp the upper carbon rod passes through a hollow core contained in a solenoid; to the lower end of the core is attached a sleeve or chamber which contains a number of balls around the rod, and arranged to grip the rod.

1882. J. BROCKIE. 1713.

Improvements in Electric Arc Lamps.

The upper carbon rod is provided with a rack, gearing into a wheel train; the regulation is effected by the release of a fly by means of an iron core contained in a solenoid forming a shunt to the arc.

1882. A. B. BROWN. 1867.

Improvements in Electric Arc Lamps.

Uses clutch for forming the arc by raising the upper carbon; the regulation is performed by means of a valve, allowing the passage of liquid from under a piston contained in a cylinder.

1882. W. T. WHITEMAN. 1915.

(From M. BAUER and Others.)

Improvements in Electric Lamps.

Improvements to Lamp described in Patent 2038, 1881.

This consists of an oscillatory horse-shoe electro-magnet, one pole of which is in juxtaposition to or in contact with an iron rod carrying one of the carbons, and the other pole of which is in contact with a magnetic brake and in proximity to a fixed block of iron, the attraction between which block and the magnet, tends to separate the carbons or to oppose their approach towards each other.

1882. J. LEA. **1919.**

Improvements in Electric Arc Lamps.

Upper carbon-holder is held in position by three rollers, two of which are fitted to a frame carrying a friction wheel, to the axle of which is fitted a pinion in which the rack of upper rod works. Two solenoids are provided; the iron cores actuate levers which control the movement of the friction wheel.

1882. T. J. HANDFORD. **2072.**
(From T. A. Edison.)

Improvements in or relating to Electric Lights.

Describes clutch actuating upper carbon-holder. Special reference to wire on coils for regulating.

1882. C. LEVER. **2092.**

Improvements in Electric Light Apparatus.

Describes clutch used to separate the carbons, actuated by a spring and lever; use of regulating coils, wound and connected, to shunt the current from arc in regulating.

1882. E. L. VOICE. **2288.**

Improvements in Electric Lamps.

Describes an arrangement in which clutches are formed from two semi-circular cores contained in a solenoid surrounding the upper carbon rod; the semi-circular cores are pivoted at their lower end, and grip the carbon rod when the current passes. The arc is formed by the cores being raised by a separate armature.

1882. J. BROCKIE. **2370.**

Improvements in Electric Arc Lamps.

In this lamp a train of wheels arranged in a rocking frame are employed; the carbons are separated by a movement of the frame, and the feeding of same is effected by an iron core contained in a solenoid releasing a brake wheel contained in the movement.

1882. W. H. AKESTER. **2419.**

Improvements in Electric Arc Lamps.

Upper carbon rod is grooved spirally in the form of a screw.

1882. T. E. GATEHOUSE and H. R. KEMPE. **2569.**

Improvements in Electric Lamps.

In this lamp the carbons are regulated by means of a reciprocating pawl, which engages with the teeth to drive a roller, which moves the carbons, and which is controlled by an electro-magnet or solenoid having its attractive force determined by the resistance of the arc.

Describes the introduction of a carbon filament in the circuit as part of the resistance.

1882. W. R. LAKE. 2570.

(From J. J. Wood.)

Improvements in Electric Lamps or Lighting Apparatus.

Employs lamp with two sets of carbons, the upper carbon rods being provided with racks into which work pinions, and on the same shaft is a wheel which is allowed to move or to be stopped by means of a lever controlled by the movement of an iron core contained in two solenoids, which are influenced by the electric current.

1882. W. E. AYRTON and J. PERRY. 2613.

Improvements in Electric Lamps.

Employs clutch levers for gripping upper carbon rod. A special form of compound iron core in solenoid is used for regulating.

1882. R. E. B. CROMPTON. 2619.

Improvements in Apparatus connected with Electric Lighting.—(Provisional.)

Uses carbons attached to sliding holders, which are connected to cords or chains so that one may move the other. Refers to Patent No. 346, 1882.

1882. W. R. LAKE. 2632.

(From J. J. Wood.)

Improvements in Electric Lamps or Lighting Apparatus.

In this lamp a vibrating wheel train meshes in one carbon-holder, and the whole of the wheel train is raised when the arc is formed. The regulation is effected by means of differential coils acting on an iron core, which regulates the movement and releases a detent from a wheel to allow it to feed.

1882. R. J. HATTON and A. L. PAUL. 2654.

Improvements in Electric Lamps.

Feed of electrodes is effected by wheel train with pawl regulating same.

1882. E. DE PASS. 2674.

(From J. Gloker.)

Improvements in Electric Arc Lamps.—(Provisional.)

An iron core contained within differential solenoids is made to press against the upper carbon-holder, the varying pressure allowing the carbon to feed.

1882. M. A. WIER. 2686.

Improvements in Electric Lamps.—(Provisional.)

Describes method by which one or both electrodes is made to revolve on its own axis at a considerable velocity.

1882. W. R. LAKE. 2712
(From F. Krizik and L. Piette.)

Improvements in Electric Lamps.

The regulator is constructed on the principle of the influence of a solenoid coil on a tapering iron core attached at its large end to the holder of one of the carbons of the lamp, and partly balanced by the other carbon and its holder.

This regulator is known as the Pilsen lamp.

1882. C. G. GUMPEL. 2723.

Improvements in Electric Lamps.

The upper carbon rod passes between guide rollers, and also causes a brake wheel to revolve; this is stopped and released by a lever actuated by core of solenoid.

1882. J. MATHIESON. 2734.

An Improved Mode of Governing the Feed of Electric Arc Lamps.

A wheel train is used for regulating feed of upper carbon; an electro-magnet placed in the derived circuit releases the wheel train.

1882. W. CHADBURN. 2755.

Improvements in and relating to Electric Lamps and Generating Electricity therefor.

When the core of a solenoid is drawn upwards the upper carbon rod passes through a gripping device, and carries a lever with it which closes the clutches and thereby grips the rod; by releasing the clutches the carbons are allowed to feed.

1882. H. H. LAKE. 2759.
(From R. R. Moffatt.)

Improvements in Electric Lamps.

The upper carbon rod is provided with a rack which gears into a wheel train. A pawl is operated by an armature of an electro-magnet, regulating the feed of the carbons.

1882. W. R. LAKE. 2992.
(From J. M. A. Gérard-Lescuyer.)

Improvements in Apparatus for Regulating the Action of Electric Arc Lamps, which Improvements are partly applicable for other purposes.

Describes lamp consisting of an arrangement of two levers which grip the upper carbon or rod.

Also describes lamp in which the upper carbon is used without a holder.

1882. E. A. SPERRY. 3025.

Improvements in Dynamo-Electric Machines—Mechanism for securing Uniformity and Controlling the Currents and Electric Lamps.

Describes armature with coils wound on an annular iron core, the poles of

field electro-magnets being arranged to present an extension of the same pole, both exterior and interior of the coils of the armature.

Describes a lamp where the upper carbon rod is clamped by a system of X levers. The movable iron core contained in a solenoid of thick wire is wound with fine wire; the movable iron core is made to actuate the levers which clamp the carbon rod.

1882. E. DE PASS. 3070.

(From C. Roosevelt and B. Abdank.)

Improvements in and applicable to Electric Arc Lamps.

A clutch or gripping mechanism is used with upper carbon rod.

1882. J. H. JOHNSON. 3079.

(From L. Bardon.

Improvements in Electric Lamps.—(Provisional.)

Upper carbon rod is provided with a helix or quick screw thread, and actuated by a lever in combination with a solenoid or electro-magnet.

1882. R. H. COURTENAY. 3101.

An Improved Arc Electric Lamp.

Employs an upper carbon rod square in section, and gripped by two wedge-shaped clamps; on their outside edges is a cross-piece of metal to which is attached the iron cores of two solenoids, which is raised, and in so doing clamps the rod.

1882. W. R. LAKE. 3204.

(From E. Thomson.)

See Dynamo and Magneto-Electric Machines of the Siemens type.

1882. F. M. ROGERS. 3236.

Improvements in Arc Electric Lamps.

Upper carbon rod is clamped by clutches in various forms.

1882. R. E. B. CROMPTON. 3339.

Improvements in Arc Regulator Lamps.

Improvements to Patent No. 346, 1882.

Describes a vibrating gearing frame with one of its wheels gearing with a connecting cord connecting the two carbon holders. In this lamp the rack or clutch rod is dispensed with.

1882. L. A. GROTH. 3385.

(From C. P. Jürgensen.)

A New or Improved Electric Arc Lamp.

Two grooved pulleys are arranged on one shaft, the large one being held by friction against the upper carbon rod, and the smaller one (which is half

the diameter of the large one) against the lower carbon rod. Two solenoids, each working direct on their respective carbon-holders, are arranged to regulate the working of the lamp.

1882. J. D. F. ANDREWS. **3393.**

Improvements in Electric Lamps.

Describes method of compensating the increase and diminution of the attractive power of the solenoid on its core as it changes its position in the solenoid. By means of a chain a greater or less number of links are by the movement of the core brought to act by gravity upon it. Also by arranging two cores to balance each other approximately within one solenoid coil.

1882. S. Z. DE FERRANTI and A. THOMPSON. **3418.**

Improvements in Electric Arc Lamps and in Regulators therefor; applicable also to Regulating Electric Currents for other purposes.

Right- and left-handed screws are used as a means to actuate the carbon-holders; a vibrating armature connected with a pawl turns a ratchet-wheel, which gears into the rack on the carbon-holders.

1882. A. GRAY and T. GRAY. **3441.**

Improvements in Apparatus for Regulating Electric Lamps and for Measuring Electrical Currents and Electrical Energy.

A hollow drum divided into compartments by partitions pierced with orifices, and containing liquid, is used for regulating the motion of the carbons.

Refers also to a form of galvanometer for measuring currents.

1882. A. RECKENZAUN. **3473.**

See Dynamo- and Magneto-Electric Machines of the Gramme type.

1882. A. M. CLARK. **3508.**

(From H. J. Müller and A. Levett.)

Improvements in Electric Lamps.

Employs a movement consisting of toothed wheels into which the carbon rods are geared, a ratchet-wheel, and pawl; the pawl is attached to a lever, which is actuated by another lever connected to the iron core of solenoid.

Describes also a switch for putting in circuit another set of carbons after one set is consumed.

1882. A. L. LINEFF. **3520.**

Improvements in Arc Electric Lamps.

Uses a solenoid with a hollow magnetic core (which also acts as an air brake) through which the carbon rod is free to slide, but when under the influence of the electric current grips the rod. Several clutches are shown.

1882. F. M. NEWTON. 3570.

Improvements in Electric Arc Lamps.

In this lamp the upper carbon rod is geared into a pinion on the shaft of which is fitted a drum containing mercury or other fluid; a number of partitions are contained within the drum, and which regulate the fall of the carbon rod when it is released; the rod is clamped by means of a small ball contained in a tapered cavity.

1882. J. G. LORRAIN. 3575.

Improvements in Eleetric Lamps.

One of the carbon rods is made to pass between two sets of rollers, and between the sets of rollers is a gripping device which acts on one side of the carbon to regulate the feed; the gripping device is connected to an armature of an electro-magnet coil.

1882. G. HENLEY and S. GEDGE. 3583.

Improvements in Electric Lamps, and in Machinery and Apparatus connected therewith for Obtaining and Transmitting Power.

Describes several forms of lamps.

In one form, the upper carbon rod is gripped and regulated by one or two gripping arms or rods connected to the armatures of electro-magnets. Several forms of gripping arms or rods are shown.

Another with upper carbon rod in the form of a spiral or screw thread, and controlled by a wheel train.

Another with two parallel carbons separated by a wedge-shaped lever passing between the bottom carbon-holders.

A dynamo-electric machine is described in which the armature coils are arranged on the periphery of a wheel; two armatures of this construction are arranged on a shaft, and revolve within the poles of the field magnets.

A mercurial commutator is also described.

1882. J. L. SOMOFF. 3705.

An Improved Construction of Electric Lamp.—(Provisional.)

Upper carbon rod is clutched by a lever on which are fitted iron armatures actuated by electro-magnet coils.

1882. E. G. BREWER. 3713.

(From Société Anonyme des Ateliers de Construction Mécanique et d'Appareils Électriques of Paris.)

Improvements in Electric Arc Lamps.

The upper carbons and lower carbons are regulated by a long spiral or screw placed in the upper part of the lamp. Arrangements for releasing the screw are described.

1882. B. J. B. MILLS. **3779.**

(From W. M. Thomas.)

Improvements in Electric Lamps.

Describes arc lamp with a stationary helix in communication with the positive carbon, a sliding conductor upon a bared track on the said helix's periphery, an interior suction core, and an exterior concentric differential shunt.

1882. W. R. LAKE. **3795.**

(From J. B. Wallace.)

Improvements in Electric Lamps or Lighting Apparatus.

Upper carbon rod is arrested and regulated by means of two jaws or clutches actuated by a lever, operated upon by means of armature of electro-magnet coils.

1882. H. WILDE. **3834.**

Improvements in Apparatus for Regulating Electric Light.—(Provisional.)

Upper carbon-holder is made to approach and separate by means of a long driving screw.

1882. F. R. WELLES. **3881.**

(From C. E. Scribner and W. R. Patterson.)

Improvements in Electric Lamps and Conductors therefor.

Various forms of clutches are described for operating on the upper carbon rod.

1882. T. J. HANDFORD. **3976.**

(From T. A. Edison.)

Improvements in or relating to Electric Lights.

Employs lamp in which upper carbon rod is operated by means of a clutch, the lamp being arranged to work in a cross or multiple-arc circuit in conjunction with incandescent lamps.

1882. W. MORGAN BROWN. **4367.**

(From F. Schmidt.)

Improvements in Systems of Electric Lighting.

Relates to the application and winding of solenoids or coils to arc lamps so that an electric current appears simultaneously in two circuits of each magnet or solenoid, thus causing a changing of polarity in the opposite currents, whereby the magnets or solenoids are caused to change or reverse their motion.

1882. H. H. LAKE. 4404.

(From S. F. VAN CHOATE.)

Improvements in Electric Lamps and in Apparatus for use in connection therewith, and for other purposes.

Describes use of clutches in the form of levers or clamps, known as "dogs," to secure the upper carbon rod. Various cut-outs and connections for attachment to posts, &c., are shown.

1882. J. K. D. MACKENZIE. 4046.

Improvements in Electric Arc Lamps and Mechanism for Electric Lighting.

Describes lamp in which the upper carbon rod is clamped by means of a split iron armature, which is operated by means of an electro-magnet.

1882. C. S. SNELL. 4065.

Improvements in Electric Lamps.—(Provisional.)

Similar to Pilsen lamp.

1882. J. G. STATTER. 4304.

Improvements in Electric Lamps.—(Void through not filing Specification.)

Describes lamp in which the rod of upper carbon-holder is fitted with a rack, which gears into a pinion on the shaft of a small motor, the regulation being effected thereby.

1882. J. BROCKIE. 4419.

Improvements in Electric Arc Lamps.

Relates to the employment of a hollow disc or drum driven by the upper carbon rod, this disc or drum being partially filled with mercury or other divided substance, such as shot or sand; the drum is provided with projections or divisions inside; a brake lever presses against the drum, and is released when it is required by means of electro-magnet coils.

1882. E. EDWARDS and A. F. ST. GEORGE. 4695.

Improvements in Electric Lamps.

Employs two electro-motors, in combination with differential gearing to regulate the feed of the carbons.

1882. O. G. PRITCHARD. 4771.

An Improvement in the Production of the Electric Light, and Means to be Employed for the purpose.

Describes a vibrating armature connected to which is the lower carbon, and thus a rapid reciprocating motion is imparted to it. The upper carbon is

fed towards the reciprocating carbon by the action of gravity, but is subject to the retarding action of a piston in a closed tube, the motion of which is controlled by the size of aperture through which the air is allowed to pass.

1882. S. F. WALKER and F. G. OLLIVER. **4780.**

Improvements in Electric Lamps and Lighting Apparatus.

An electro-motor, in combination with a lever or clutch, is used to regulate the feed of the carbon.

1882. W. STRICKLAND. **4869.**

Improvements in Electric Lighting and in the Apparatus to be used therefor.

Relates to use of a contact-keeper or armature at the points of the pencils; also the combination of carbon pencils arranged two on each side of a slip of refractory material.

1882. A. M. CLARK. **4880.**

(From W. S. PARKER.)

Improvements in Electric Arc Lamps.

The upper carbon rod is regulated by a lever clutch operated by an oscillating arm, to each of which is attached an iron core contained in solenoids.

1882. J. ALLMANN. **4911.**

(From L. E. SCHWERD and L. SCHARNWEBER.)

Improvements in Electric Lamps.—(Provisional.)

The regulation of the carbons is effected by a fluid resistance acting upon a piston working in a cylinder and connected to an escapement.

1882. C. S. SNELL. **4930.**

A New or Improved Electric Arc Lamp.

In this lamp the feeding of the carbons is regulated by a brake lever, which is acted upon by means of a spiral spring which forms the core of a solenoid, within which spring the carbon rod passes.

1882. A. SERRAILLIER. **4988.**

Improvements in the Construction of Electric Arc Lamps.

Two sets of automatic grippers in the form of small balls, contained in a chamber with slanting inner sides which surround the upper carbon rod, are used to regulate the feed of the carbons.

Also describes a lamp with the carbons arranged at an angle, with the apex upwards.

1882. P. CARDEW. **5105.**

(*See* Dynamo- and Magneto-Electric Machines of the Gramme type.)

1882. W. R. LAKE. 5142.

(From B. EGGER.)

Improvements in Electric Lamps or Lighting Apparatus.—(Provisional.)

This regulator is provided with a train of wheels, which is set going by the rack on the carbon rod engaging in a pinion connected with same; an oscillating lever with an iron core at each end is used for releasing the movement, the cores being contained in solenoids.

1882. F. L. WILLARD. 5174.

Improvements in Arc Electric Lamps.—(Provisional.)

Two cams are arranged to secure the upper carbon rod; the cams are raised and released by a slot link actuated by an iron core, which is actuated by solenoids.

1882. BARON ELPHINSTONE, C. W. VINCENT, and J. COTTRELL. 5495.

Improvements in Electric Arc Lamps.

Relates to the application of a pneumatic apparatus in combination with a solenoid for controlling the feed of the carbons.

1882. W. R. LAKE. 5796.

(From R. H. MATHER.)

Improvements in Electric Lamps or Lighting Apparatus.

The upper carbon rod is secured and regulated by means of a spring clamp, the rod passing through a hollow iron core contained in a solenoid, by which the clamp is released when the carbons are required to be released.

1882. F. H. F. ENGEL. 5910.

(From F. KÜPPERMANN.)

Improvements in Electric Lamps.—(Provisional.)

Both carbon-holder rods are arranged to gear into a wheel train, the movements being effected by a rachet or pawl, which is formed of a double-armed lever that fulcrums on a pin; one end of this lever stops the ratchet-wheel, and also releases it when the carbons are required to be released.

1882. H. H. LAKE. 6046.

(From J. KREMENEZKY.)

Improvements in Electric Lamps or Lighting Apparatus.—(Provisional.)

The upper carbon rod is made to pass through the centre of a hollow core contained in a solenoid; to the bottom of the iron core two pawls are fitted by links, which are pivoted to a fork attached to a socket through which the rod slides. The regulation is effected by actuating the socket.

1882. **A. M. CLARK.** 6185.

(From La Socéité Solignac et Cie.)

An Improved Electric Arc Lamp.

Describes an arc lamp in which a block of carbon, serving both as electrode and as reflector, is employed in combination with an annular cup of refractory material.

1882. **W. R. LAKE.** 6237.

(From R. Mondos.)

Improvements in Electric Lamps or Lighting Apparatus.

Describes arrangement in which upper carbon rod is formed with a rack, connected by gearing with a ratchet-wheel acted on by a pawl, and a counter-weight which serves as a brake.

1883. **F. J. CHEESBROUGH.** 4.

(From E. R. Knowles.)

Improvements in Electric Lamps of the Arc type.

Describes an arc lamp in which the feed of the carbons is arrested by a clutch lever, and being allowed to feed on their release by means of a lever at each end of which is an iron core contained in solenoids.

1883. **W. R. LAKE.** 34.

(From C. A. Hussey and A. S. Dodd.)

Improvements in Electric Lamps or Lighting Apparatus.

The upper carbon rod passes through a hollow iron core, formed of two concentric cylinders with their upper ends closed; between the inner and outer core there is a fixed coil of fine wire, and on the outside of the double core there is a coil of thick wire; two clamps or clutches which grip the rod are actuated by the double core.

1883. **J. G. LORRAIN.** 183.

Improvements in Electric Arc Lamps.

Upper carbon rod secured by means of two jaws or clutches; these are connected to a hollow core through which the rod passes, the hollow core being contained in a solenoid.

1883. **B. J. B. MILLS.** 1620.

(From O. A. Moses.)

Improvements in Voltaic Arc Lamps.

The upper carbon-holder is formed of a tube containing liquid, and works through a hollow coil; the plunger or piston is formed of a piece of iron, which forms also the core of the solenoid.

1883. F. H. VARLEY. 1745.

Improvements in Electric Lamps and Appliances connected therewith.

Describes a lamp constructed for burning the flexible carbons made according to Varley's Patent 2776, 1882.

1883. F. MORI. 322.

Improvements in Electric Arc Lamps.

In this lamp the upper carbon rod is provided with a rack, into which is geared a pinion which carries on the same shaft a wheel controlled by an endless screw or worm; the whole is fitted into a metal frame, and raised by a lever to which is attached an iron core contained in a solenoid.

1883. H. H. LAKE. 361.

(From H. R. BOISSIER.)

Improvements in Electric Lamps or Lighting Apparatus.

The upper carbon rod is provided with a rack, into which a pinion is geared. On the same shaft as the pinion is a wheel which works a fly or disc, or a detent wheel, the movement of which is controlled by a lever which is actuated by the movement of an iron core contained in two solenoids. The movement is contained in a swinging frame.

1883. A. E. SWONNIKOFF. 371.

Improvements in Electric Lamps.

In this lamp the upper carbon rod is provided with a rack, into which is geared a pinion. On the same axis as the pinion is fixed an escape-wheel, the teeth of which are engaged by the pallets of an anchor; this anchor is on the arm of a lever which carries an armature for an electro-magnet, or a core in a solenoid. Also shows arrangement for putting on circuit another set of carbons.

1883. A. GRAY and T. GRAY. 634.

Improvements in Apparatus for Regulating Electric Lamps, Electric Currents, Electric Potentials, and the Supply of Electric Energy.—(Provisional.)

Improvements to Patent 3441, 1882.

Relates to the use of a motor in combination with a fly only for regulating release of carbons in arc lamps.

Describes also the use of a current regulator, which is constructed with a motor, and an arrangement for introducing resistance into or to take it out of circuit, the object being to render the electro-motive force uniform.

1883. H. TROTT and C. F. FENTON. 951

An Improved Electric Arc Lamp.—(Provisional.)

Describes a lamp in which the upper carbon rod is provided with a rack, which gears into a wheel train, to the fourth wheel of which is attached an

iron disc or wheel armature, which rotates at the poles of an electro-magnet, the electro-magnet being wound with thick wire in main circuit, and wound with fine wire in shunt circuit in opposite direction.

1883. H. H. LAKE. **1171.**

(From E. Weston.)

Improvements in Electric Lamps or Lighting Apparatus.—(Provisional.)

Describes a lamp in which the upper carbon rod passes through a clutch, which is actuated by suitable coils.

1883. J. E. L. CLARK, W. J. K. CLARK, and R. D. BOWMAN. **1182.**

Improvements in Electric Arc Lamps.

The upper carbon rod is secured by the pressure of a spring, which is actuated by a lever connected to an armature or iron core of an electro-magnet or solenoid.

1883. E. JONES and A. E. JONES. **1202.**

Improvements in Electric Arc Lamps.

Describes a lamp where the release of carbons is regulated by a cord, which is attached to the carbon-holders, passing between two rollers or pulleys which grip or release the cord; one of the pulleys is attached to a lever, which is operated by a core contained in a solenoid.

Another form of lamp is described where a lever carries a train of wheels; a fly or star wheel is released when the carbons are required to feed.

1883. J. G. STATTER. **1255.**

Improvements in Electric Lamps and Fittings therefor.

Describes lamp in which the upper carbon rod is provided with a rack, which gears into a pinion on the shaft of a small motor. An automatic switch for shunting the current through the motor when the carbons are required to feed is provided.

1883. F. M. NEWTON. **1623.**

Improvements in Electric Arc Lamps.

Describes a device set in vibratory motion by a make-and-break apparatus when the arc exceeds its normal length, and which continues in vibratory motion until it has restored the arc again to its normal length; the device being formed of elastic fingers or feelers, which grasp the carbon or its holder during one part of the vibration, feeding it forward, and slide over it during the opposite or reverse part of its vibration.

1883. T. WIESENDANGER. **1759.**

See Dynamo- and Magneto-Electric Machines—Miscellaneous.

1883. J. HENRY and H. B. BOURNE. 1760.

An Improved Method of, and Appliance for, Feeding the Carbons of Electric Arc Lamps.

Upper carbon rod is held in position by a clutch, and is provided with a hammering or tapping device for feeding the rod through the clutch.

1883. L. B. MILLAR. 1774.

Improvements in Electric Arc Lamps.—(Provisional.)

The upper carbon rod passes between friction rollers, and also between several armatures which press against the rod. The feed is effected by the armatures being drawn off the rod by the electro-magnets.

1883. J. T. KING. 1753.
(From J. R. FINNEY.)

Improvements in and applicable to Electric Arc Lamps.

Upper carbon rod passes through hollow core contained in solenoid, the rod being held by two gripping jaws; the jaws are actuated by the movement of the hollow core.

1883. W. HOCHHAUSEN. 2057.

Improvements in Electric Lamps and Circuit Connections, and Apparatus for the same.

In this lamp each of the upper carbon rods is provided with a rack, which gears into mechanism connected with an escapement device on a lever, which arrests the movement of the escapement, and is actuated by an iron core contained in a solenoid.

1883. S. PITT. 2205.
(From L. DAFT.)

See Dynamo- and Magneto-Electric Machines of the Gramme type.

1883. A. SHEDLOCK. 2337.

Improvements in and relating to Electric Lamps or Lighting Apparatus.

Relates to lamp in which the upper carbon rod is gripped by a spiral sprnig which surrounds the rod.

1883. R. E. B. CROMPTON. 2539.

Improvements in Arc Regulator Lamps.

Relates to the construction of arc lamp where the feed of the carbons is controlled by a vibratory lever acting as a brake on a disc.

1883. P. JOLIN and J. PARSONS. 2570.

Improvements in Electric Arc Lamps.

In this lamp the carbon rod is gripped between blocks hinged one to the other.

Describes also various other devices for same purpose.

Also describes various details of construction of lamps, such as carbon-holders, &c.

1883. J. BROCKIE. **2661.**

Improvements in Electric Arc Lamps.

Employs hollow discs or drums having swinging or rolling weights in their interior, in combination with some glutinous substance such as glycerine; also hollow drums containing mercury with a glutinous substance; also discs of metal controlled by friction brakes.

1883. F. L. WILLARD. **2743.**

Improvements in Mechanism for Regulating Electric Arc Lamps.

Describes lamp in which the carbons are regulated by an escapement device. Also relates to various circuit-shunting devices used in the lamp.

1883. A. GRAY and T. GRAY. **2804.**

See Dynamo- and Magneto-Electric Machines—Miscellaneous.

1883. H. J. ALLISON. **2872.**
(From W. Baxter, Jun.)

Improvements in the Manufacture of Electric Arc Lamps.

Relates more especially to the combination of an electric arc lamp arranged with an air-tight receiver to enclose the contiguous carbon points, and a slip joint or packing through which the moving carbon may enter the receiver without permitting the gases to pass to the regulating mechanism.

1883. W. P. THOMPSON. **2895.**
(From R. J. Sheehy.)

Improvements in the Production of Light by Electricity, and in Apparatus therefor.

Describes lamp in which the upper carbon-holder is moved by clamping wheels pivoted upon eccentric bearings, the clamping wheels being provided with mechanism for revolving same. Also relates to the use in combination with arc lamps, of a signalling apparatus for opening the main circuit a predetermined number of times.

1883. S. PITT. **3000.**
(From N. H. Edgerton.)

Improvements in Electric Arc Lamps.

Describes arc lamp with fixed lower electrode of irreducible material, combined with an upper movable electrode, being a carbon pencil, free to gravitate with respect to an arc interval between it and the fixed electrode; also a chamber or fixed magazine adapted to contain a series of carbon pencils arranged to successively gravitate therefrom.

1883. T. H. S. HAWKER. 3003.

Improvements in the Construction of Arc Lamps, and in Apparatus for Generating Electric Currents for Electric Lighting and other purposes.—(Provisional.)

Relates to the use of a reversible electro-motor, in combination with a pole changer actuated by a differential solenoid, for regulating release of carbons.

1883. W. P. THOMPSON. 3031.
(From R. J. Sheehy.)

Improvements in the Production of Light by Electricity, and in Apparatus therefor.

The upper carbon rod passes between rollers; the movement of the rod is controlled by a cord, which is arrested or released by a clamping device.

1883. C. WÜEST. 3233.

Improvements in Electric Arc Lamps.

In this lamp both the upper and lower carbon are brought nearer to one another, or separated, by a right- and left-handed screw which gears into worm wheels attached to each carbon-holder.

1883. A. L. LINEFF. 3333.

Improvements in Electric Arc Lamps.—(Provisional.)

Describes regulator constructed of a wheel train, the movement being arrested or released by the fly.

1883. F. M. NEWTON. 3392.

Improvements in Electric Arc Lamps.

Relates to the use of an oscillating or rocking device lined with elastic or spring arms, or fingers, so arranged that while one part is advancing carrying the carbon towards the arc, the other part is receding into position for the next forward movement.

1883. E. G. BREWER. 3779.
(From La Société Anonyme des Ateliers de Construction Mécanique et d'Appareils Électriques.)

Improvements in the Mode of, and Apparatus or Appliances for, the Regulation of the Movement of the Carbons or Electrodes in Electric Lamps.

A spiral thread is formed of the upper carbon rod, the movement of which is controlled by a locking nut actuated by iron cores of solenoids.

1883. W. R. LAKE. 3827.
(From La Société F. Gérard et Cie.)

Improvements in Electric Lamps or Lighting Apparatus.—(Provisional.)

The upper carbon rod is clamped by two rollers, which are attached to

levers operated by an iron core contained in a solenoid, and caused to act by shunt or derived circuit.

1883. A. W. RICHARDSON. **4269.**

Improvements in Electric Lamps.—(Provisional.)

Relates to lamp with wheel train, the upper carbon rod gearing into same, a brake wheel being provided in the wheel train on which a lever acts, being operated by electro-magnets.

1883. J. R. P. WALLACE and F. CHERRY. **4281.**

Improvements in Electric Lamps.

Both carbons are movable. When no current is passing one carbon is held away from the other; the carbons are brought together when a current is passed through the lamp, and separated again, the regulation being effected by a wheel train and an escapement-wheel and stop-piece.

1883. H. W. PENDRED. **4815.**

Improvements in Electric Arc Lamps.—(Provisional.)

In this lamp the upper carbon rod is provided with a rack, which gears into a wheel train, the frame of the wheel train being hung on centres; a brake wheel is provided to the wheel train. The frame, with the movement, is raised or lowered by means of solenoid core, the movement of the wheel train being stopped by the brake-wheel being arrested.

1883. W. H. AKESTER and R. MITCHELL. **4875.**

Improvements in Electric Arc Lamps.—(Provisional.)

In this lamp the upper carbon rod passes through a hollow iron core contained in a solenoid, the rod being held when the lamp is in operation by a ring which surrounds the rod, and is acted on by projections on the iron core.

In another form of lamp, a rack gearing with a spur-wheel is described.

1883. H. J. HADDAN. **4914.**

(From Dr. E. Boettcher.)

Improvements in Electric Arc Lamps.—(Provisional.)

Relates to a lamp in which mechanism is used to control the movement of the carbons, but does not describe in detail how it is arranged.

1883. H. J. HADDAN. **5252.**

(From F. H. Werner.)

Improvements in Electric Arc Lamps.—(Provisional.)

The upper carbon rod is provided with a rack, which gears into a wheel train, the wheel train being provided with a brake-wheel, which is arrested or released by suitable electro-magnets.

1883. H. SPRINGMANN. 5299.

(From H. A. EARLE.)

Improvements in Electric Arc Lamps.—(Provisional.)

Relates to the regulation of feed of carbons by means of flow of liquid contained in a cylinder.

1883. H. H. LAKE 5472.

(From T. J. McTIGHE and J. T. McCONNELL.)

Improvements in Electric Lamps or Lighting Apparatus.

The upper carbon rod is provided with a rack, which gears into a pinion on the shaft of which is an escapement-wheel, the escapement-wheel being arrested by a pawl, which is removed from the teeth of the wheel by an electro-magnet armature.

1883. C. M. SOMBART. 5924.

(From B. SOMBART & Co.)

Improvements in Electric Arc Lights.—(Provisional.)

Describes a lamp in which the upper carbon rod is operated by a form of clutch actuated by a lever connected to armatures of electro-magnet coils.

1884. J. BROCKIE. 898.

Improvements in Arc Lamps.—(Provisional.)

Relates to regulating the feeding of electrodes by the use of a star or ratchet wheel controlled by a regulating magnet and detent.

1884. M. H. HURRELL. 1790.

Improvements in Electric Arc Lamps.—(Provisional.)

The upper carbon rod is provided with a rack, which gears into a pinion having an escapement-wheel on its axis; a lever carrying the pallets are acted upon by a solenoid or electro-magnet coils.

1884. J. BROCKIE. 2059.

Improvements in Arc Lamps.—(Provisional.)

Describes a method of arranging the circuit and regulating relay.

1884. H. W. PENDRED. 3210.

Improvements in Electric Arc Lamps.

The movement of the upper carbon is controlled by a wheel train mounted in a swinging frame; a brake-wheel is provided, and is arrested or released by a stop-piece provided for that purpose.

1884. W. GEIPEL. 3885.

Improvements in Electric Arc Lamps.—(Provisional.)

The upper carbon rod passes between two rollers placed on opposite sides of the rod, one of which is connected to a wheel train, and the other to a lever,

and arranged to grip or hold the rod; in this arrangement having two feeding mechanisms, one of which comes into operation in the event of mishap to the other feeding action.

1884. F. THORNTON and O. ROMANZEE. **3901.**

Improvements in Electric Arc Lamps.—(Provisiona.)

Relates to the construction of an arc lamp having a bar capable of slight endway up and down movement, and secured to it a core of iron acted upon in opposite directions by the electric current passing through two coils; a screw mounted lengthwise on the bar and a lock nut are provided. An escapement is also arranged to regulate the downward movement of the rod carrying the carbon.

1884. H. F. JOEL. **3970.**

An Electric Light Arc Lamp.—(Provisional.)

In this lamp the upper carbon rod is held by gripping-pieces attached to links connected to the hollow iron core, by the movement of which the rod is released or its motion arrested.

1884. H. H. LAKE. **4552.**

(From F. H. Werner and L. Ochse.)

Improvements in Electric Lamps or Lighting Apparatus.—(Provisional.)

The upper carbon rod is provided with a rack, and gears in a pinion connected with a wheel train; a brake-wheel is also provided, on which an arm rests, and is actuated by a lever connected with armatures of electro-magnets.

1884. H. TROTT and C. F. FENTON. **6910.**

An Improved Electric Arc Lamp.

The upper carbon rod is made with a longitudinal groove, in which a metallic band rests; this metallic band passes round a pulley or drum which is controlled by a wheel train; a wheel armature connected to the wheel train rotates between the poles of a controlling electro-magnet.

1884. R. E. B. CROMPTON and T. CRABB. **8063.**

Improvements in Regulating Apparatus for Electric Arc Lamps.—(Provisional.)

Relates to the use of a compensating lever as a means of actuating the feed mechanism of arc lamps.

1884. T. CUTTRISS. **8865.**

Improvements in Mechanism for Regulating Electric Arc Lamps.—(Provisional.)

The upper carbon rod is provided with a rack, which gears into a pinion; a rocking frame which carries the pinion and a ratchet-wheel is controlled by the movement of a core at one end of the frame.

1884. C. LEVER. 11501.

Improvements in Electric Arc Lamps.

Relates to improvements to a lamp described in Patent No. 2092, 1882, and describes method of arranging the regulating coils so that the lamps may be more effectively worked in series.

1884. A. W. RICHARDSON. 13392.

An Improved Electric Arc Lamp.

In this lamp the upper carbon-holder is controlled by a wheel train, which is provided with a verge escapement and brake-wheel, and a brake lever actuated by differential coils.

1884. F. THORNTON and O. ROMANZEE. 15030.

Improvements in Electric Arc Lamps.

The upper carbon rod is provided with a rack, the teeth of which are cut at an angle so as to gear into and work an endless screw, the movement being controlled by an escapement.

1884. A. PFANNKUCHE. 12626.

Improvements in Electric Arc Lamps.

The movement of the upper carbon rod is controlled by a compound or double clutch, having its two connected parts arranged at different heights.

1884. G. E. VAUGHAN. 15566.

(From The Austrian Small Arms Manufacturing Company.)

Improvements in Regulating Apparatus for Electric Arc Lamps.

The movement of upper carbon is controlled by a wheel train. Describes method of release by shunt coils acting at a certain length of arc.

1885. R. P. SELLON. 639.

Improvements in Electric Arc Lamps.

A wheel train is used to regulate the upper carbon, and the release is only allowed to take place when the electro-motive force is above, or the current below, its normal. The arc is formed by lower carbon being operated by an electro-magnet.

1885. W. J. MACKENZIE. 1621.

Improvements in Electric Arc Lamp.

Improvements to Arc Lamp described in Patent No. 95, 1882.

Describes a lamp the movement of upper carbon of which is regulated by a reciprocating electro-motor, and gives movement to an endless screw, into which gears a wheel; on the same shaft is a pinion which gears into the rack of upper carbon rod.

1885. T. NORDENFELT. **1854.**

(From O. F. Jönsson.)

An Improved Electric Arc Lamp.

Describes a lamp the upper carbons of which are counterbalanced by weights and chains, in order to reduce the power required to a minimum.

1885. J. G. STATTER. **2985.**

Improvements in Electric Arc Regulators.

Regulation of release of upper carbon rod is controlled by a brake-wheel fitted on same shaft as the pinion into which the rod gears; controlling coils release and stop the brake-wheel.

1885. H. W. PENDRED. **4110.**

Improvements in Electric Arc Lamps.

Relates to improvements to lamp described in Patent 3210, 1884. An escape-wheel and pallets are substituted for the brake-wheel. Other details are described.

1885. H. PIEPER. **4647.**

New Electric Arc Lamp.

The movement of the upper carbon rod is controlled by two friction blocks attached to one lever actuated by an electro-magnet. Arc is formed by lower carbon.

1885. C. STREET and F. V. MAQUAIRE. **9666.**

Improvements in Electric Arc Lamps.

Describes movement of upper carbon rod controlled by two electro-motors. The arc formed by lower carbon.

1885. G. E. VAUGHAN. **12551.**

(From The Austrian Small Arms Manufacturing Company.)

Improvements in Regulating Apparatus for Electric Arc Lamps.

Relates to improvements in lamp described in Patent 15566, 1884. The upper carbon-holder is counterpoised by a weight and regulated by a roller clutch. Improvements in winding regulating coils are also described.

II.—MISCELLANEOUS.

1882. J. D. F. ANDREWS. **1324.**

(*See* Lamps—Arc—Vertical Carbons.)

1882. J. H. JOHNSON. 2144.

(From J. M. A. Gérard-Lescuyer.)

Improvements in Electric Lamps.

Describes a lamp in which the carbons are arranged parallel to each other. When they are placed in circuit the current passes up one of the carbons and descends by the other, and as the two parallel currents in opposite directions repel each other, this repulsion suffices to cause the oscillating carbon to move away from the fixed one and thus establish the arc.

1882. R. KENNEDY. 2286.

Improvements in Electric Lamps of the Arc type.

Improvements to Patent No. 1199, 1882.

Substitutes a coil of soft iron wire wound on a wooden or brass or other non-magnetic substance instead of the soft iron tube described before.

1882. W. R. LAKE. 2781.

(From C. F. de la Roche.)

Improvements in Electric Lighting Apparatus.

The carbons are arranged horizontally, and are contained in tubes; at the end of the tubes nearest the arc is a ring forming an abutment for the carbons, and a ring arranged so that the electrode is segregated by the action of air and heat, thus facilitating the progressive and regular advance of the carbons. The carbons are pressed forward by means of a spiral spring.

1882. S. H. EMMENS. 2914.

Improvements in Electric Lamps and in Appliances relating thereto.

Describes lamp with parallel carbons, the carbons being raised by weights, and held and released by a set of double levers. A method of arranging the carbons to converge at their lower extremities is shown, also a lamp where the upper carbon passes through the centre of an iron core, and is gripped by contact discs on both sides of the carbon.

1882. H. J. HADDAN. 3382.

(From H. A. Seymour.)

Improvements in Electric Light Apparatus.

Describes method of arranging flexible supporting conductors to arc lamp by a combination of pulleys, &c. Also describes the arrangement of a yielding disc for supporting the carbons and hermetically sealing the same to the neck of the bulb.

Uses filament for lamp composed of paper, carbonised, &c.

Describes a method of manufacturing filaments by subjecting pulp or sheet fibre to great pressure, and compressing and condensing same, and afterwards forming the blank, and carbonising.

1882. J. G. LORRAIN. 3575.

See Lamps—Arc—Vertical Carbons.

1882. G. HENLEY and S. GEDGE. 3583.

See Dynamo- and Magneto-Electric Machines of the Gramme type.

1882. W. R. LAKE. 3856.

(From N. E. REYNIER.)

Improvements in Electric Lamps or Lighting Apparatus.—(Provisional.)

This lamp consists of two carbon plates placed parallel to each other and in the same plane.

1882. W. R. LAKE. 3906.

(From P. TIHON and E. RÉZARD.)

Improvements in Electric Lamps or Lighting Apparatus.

Describes lamp in which a rod of refractory material is used, bearing against two carbon rods.

1882. A. SERRAILLIER. 4988.

See Lamps—Arc—Vertical Carbons.

1882. A. MACKEAN. 5098.

(From A. KRYSZAT.)

Improvements in and connected with Electric Lamps.—(Provisional.)

Relates to holders for carbons when arranged parallel to each other, and for automatically switching another set of carbons in circuit.

1882. W. B. FITCH. 6235.

Improvements in Electric Arc Lights or Lamps.

Constructs and applies to arc lights a perforated disc, ring, or bulb of refractory material between the carbons.

1883. F. J. CHEESBROUGH. 5:

(From E. R. KNOWLES.)

Improvements in Electric Lamps or Lights of the Arc type.

Describes flat carbon plates arranged with their surfaces parallel to each other. One of the plates is attached to a holder operated by an armature in conjunction with an electro-magnet.

1883. J. A. BRIGGS. 187.

Improvements in the Mode of Producing Electric Light.—(Provisional.)

Relates to the placing in the focus of the arc of a refractory substance, but does not describe the manner of employing same.

1883. **A. KRYSZAT.** 520.

Improvements in Electric Arc Lamps.

Relates to holders for parallel vertical carbons, and mechanism for shunting one set of carbons in circuit after another.

1883. **J. G. LORRAIN.** 639.

Improvements in Electric Lamps.

Relates to improvements in lamps as described in Patent 3575, 1882.

1883. **F. M. NEWTON.** 867.

See Dynamo- and Magneto-Electric Machines—Miscellaneous.

1883. **W. R. LAKE** 1617.
(From C. Dion.)

Improvements in Electric Lamps or Lighting Apparatus, and in Carbon Conductors for the same.

Relates to an arc lamp with the carbons placed horizontally. The carbons are contained in tubes, the ends of the carbons abutting against projecting pieces, and are pressed forward by means of spiral springs.

1883. **T. COAD.** 1652.

Improvements in Electric Safety Lamps.—(Provisional.)

Same as described in Patent No. 1440, 1883.

1883. **A. P. LUNDBERG.** 1871.

Improvements in Electric Lamps.—(Provisional.)

In this lamp the carbons are placed in holders, and arranged obliquely, their points resting on a stop-plate. One of the holders is actuated by an electro-magnet in forming the arc.

1884. **J. BROCKIE.** 2059.

See Lamps—Arc—Vertical Carbons.

1884. **C. D. ABEL.** 5026.
(From T. Basilevsky.)

Improvements in Electric Arc Lamps.

Relates to a lamp in which the carbons are placed parallel in a vertical position. Describes also an automatic switch arrangement whereby one set of carbons are placed in circuit after one has been used.

1884. **P. M. JUSTICE.** 7962.
(From S. H. Short.)

Improvements in Electric Arc Lamps.—(Provisional.)

Relates to the use with an arc lamp of a globe or chamber for the arc, closed air-tight.

1884. **R. H. GOULD.** 10847.

An Improved Electric Arc Lamp.

Describes an arc lamp in which the carbons are inclined the one to the other, and cross or pass each other, and are made to abut against stops, whereby the distance between them is maintained for the formation of the arc.

1884. **G. PITT.** 10951.

(From C. BECK.)

Improvements in Electric Lamps.

Relates to the construction of a lamp consisting of a globe charged with a chemically inert gas, and containing also a supply of comminuted refractory material capable of being rendered incandescent by the action of electrical discharges between a pair of electrodes arranged within the globe. Below the lamp is arranged an induction coil and a voltaic battery, the combination forming a portable lamp.

1884. **C. A. ALLISON.** 12792.

(From Dr. C. A. VON WELSBACH.)

Improvements in Electric Lamps.

Describes a form of lamp in which the electrodes are made of discs of metal or carbon, and are revolved by means of a small motor; an induction coil is used to spark across a space between the electrodes. In another form of lamp a vibrator is used to vary the interval of space between the electrodes.

1884. **T. J. HANDFORD.** 13913.

(From R. H. MATHER.)

Improvements in Electric Arc Lamps.

Describes the constructing, combining, and connecting of the elements of series of single arc lamps so as to make a duplex or multiplex lamp.

INCANDESCENT.

I.—SEMI-INCANDESCENT.

1882. **R. WERDERMANN.** 1444.

Improvements in Electric Incandescent Lighting Apparatus.

A carbon pencil is kept in contact with a carbon or metal electrode of larger cross sectional area, either by springs, by a weight, or by liquid pressure.

1883. **J. UNGER.** 285.

Improvements in Electric Lamps.—(Provisional.)

Employs a carbon rod supported by a float. The carbon rod is continually

pressing against the iron cylinder. The liquid contained in the brass tube is of such a nature as to increase the capacity of the carbon, such as a solution of chloride of zinc.

1883. A. PARTZ. 1848.

Improvements in Electric Lamps.—(Provisional.)

Describes a semi-incandescent lamp in which a copper-plated carbon rod is contained in an upright metal tube. A piece of carbon in the shape of a cone, or presenting a plain or curved incline of about forty-five degrees, on which the stick of carbon rests.

1883. W. R. LAKE. 2769.
(From C. L. R. E. MÉNGES.)

Improvements in and relating to Electric Lamps and Apparatus to be used in the Manufacture of the same.

Relates to lamps in which the two carbon points are kept continually in contact under constant pressure.

Relates also to the placing of the carbons in an enclosed space filled with air or other gas, or in a vacuum.

Describes also the use of metallised carbons, and also flat carbons which are inclined to each other, their broad sides touching.

1885. T. NORDENFELT. 1856.
(From O. F. JÖNSSON.)

An Improved Semi-Incandescent Lamp.

In this system a carbon rod rests on a copper block, and both are enclosed in an air-tight globe in which is contained an inert gas, chiefly azolic gas and carbonic acid, by which the carbon will be consumed very slowly and the light rendered uniform.

II.—MISCELLANEOUS.

1882. J. WAUTHIER. 1172.

Improvements in Incandescent Electric Lamps, and in Apparatus employed in the Manufacture of Carbon Filaments therefor.

Describes filaments made with one limb straight, and the other coiled and encircling the straight limb.

Describes also an exhaustion tube fitting into the neck of the glass globe.

1882. J. B. ROGERS. 1288.

Improvements in Incandescent Lamps, and in Fittings and Switches for Electric Light Apparatus.

Connects the platinum ends to the limbs of the filament by means of inside conical tubes.

Describes various sockets for lamps.

1882. J. D. F. ANDREWS. **1324.**

See Lamps—Arc—Vertical Carbons.

1882. D. GRAHAM and H. J. SMITH. **1392.**

Improvements in Incandescent Electric Lamps, and in the Preparation of Carbons for the same.—(Provisional.)

Filaments made in the form of a circle, or may be oval, forming an endless band. Contact is made on opposite sides of the circle through holes cut in the band.

1882. T. E. GATEHOUSE. **1400.**

Improvements in Incandescent Electric Lamps.

Describes compound conductor consisting partly of material, such as platinum, whose electric resistance increases with elevation of temperature, and partly of another material, such as carbon, whose resistance decreases with elevation of temperature. The two conductors are connected in series.

1882. O. E. WOODHOUSE and F. L. RAWSON. **1412.**

Improvements in Electric Lighting and Apparatus connected therewith.

Describes lamp globes made one half opaque and other half transparent. The inner surface of the opaque half is used as a reflector, the reflecting surface consisting of silver, tin, or other substance.

Makes conductor partly of carbon and partly of metal, connected in series.

1882. S. WATERS. **1462.**

Improvements in Electric Lamps.

Silvering one half of globe, &c.

See Woodhouse and Rawson (No. 1412, 1882).

1882. SIR D. SALOMONS. **1580.**

Improvements in Electric Lamps.

Describes the following devices :—

Around a piece of pipeclay is placed some carbon composition, or platinum sheet; they are then placed in an exhausted glass tube.

A sphere of quartz with a hole bored through its centre and filled with carbon composition, and placed in vacuum.

A ball of carbon and a pointed piece of carbon rod in vacuum.

1882. J. B. ROGERS. **1618.**

Improved Arrangement of Incandescent or other Electric Lamp to render it Portable and capable of being fitted temporarily at any available place or position, and removable therefrom at will.

Methods of fittings to lamps so that they may be readily placed in the sockets, &c.

1882. ST. G. LANE FOX. 1647.

Improvements in Manufacture of Incandescent Electric Lamps.

Produces by means of the electric arc the necessary heat to cause a deposit of carbon upon the ends of the filament when immersed in a medium of coal gas or other carbon compound, the purpose being to thicken the ends of the filament.

1882. HON. R. BROUGHAM and F. R. ORMISTON. 1697.

Improvements in Manufacture of Incandescent Electric Lamps.

Describes method of fixing the ends of the filaments to the conductors, which pass through the glass.

1882. T. FLOYD and I. PROBERT. 2226.

An Improved Incandescent Electric Lamp.—(Provisional.)

One or more fibres are used as filaments, and are attached to wires which are sealed at the top and bottom of the glass globe.

Proposes to use a reflecting ball enclosed by the filaments.

1882. J. M. STUART. 2233.

Improvements in Elcctric Lamps.

Describes the use of animal carbon combined with vegetable or mineral carbon.

Exhausts air from globes by first rarefying the contained atmosphere by the use of ether, then exhausting; carbonic acid is then introduced, and again exhausted; the globe is then sealed.

1882. J. J. BARRIER and F. T. DE LAVERNÈDE. 2425.

Improvements in Incandescent Electric Lamps and in the Carbons therefor.

Describes glass globes semi-elliptical in form and provided with two cylindrical necks, one at each end.

Carbon filaments coated with amorphous phosphor and pure sulphur. When the passage of the electric current renders the carbons incandescent the phosphor and sulphur burn, and furnish phosphoric acid and sulphurous acid in abundance in absorbing the oxygen; the carbons are preserved by this action, and the light given superior to that obtained in vacuo.

1882. G. G. ANDRÉ. 2432.

Improvements in and connected with Incandescent Electric Lamps.

Improvements to Patent 4654, 1881.

Describes improved method of treating fibres so as to properly impregnate them with oxidised oil.

Filament consisting of two straight parts or halves, which converge to a very short and thicker bend or angle.

1882. G. ZANNI. **2740.**

Improvements in Electric Lamps or Lighting Apparatus.—(Provisional.)

Uses light-emitting conductor composed of a wire of platinum or similar metal covered or coated with carbon.

Also uses carbonised material coated with platinum or similar metal.

1882. A. SWAN. **2898.**

Improvements in the Manufacture or Construction of Incandescent Electric Lamps, and in Machinery or Apparatus to be employed therein.

Describes machinery and apparatus for making globes, filaments, electrodes, &c.

1882. F. L. WILLARD. **3042.**

Improvements in Incandescent Electric Lamps.

Describes filament made from veneer, known as "white lines," cemented to the leading-in and connecting wires, so that the connecting wire contracts or expands into a bulb containing mercury.

1882. A. R. LEASK. **3161.**

Improvements in or relating to Incandescent Lamps.—(Provisional.)

Simply relates to the shape of globe, and describes it as being in shape like an ordinary wax candle.

1882. W. R. LAKE. **3204.**

(From E. THOMSON.)

See Dynamo- and Magneto-Electric Machines of the Siemens type.

1882. J. S. BEEMAN. **3279.**

Improvements in Electric Lamps.

Describes the use of mica, talc, glass, or other non-conducting material, as a possible support to the carbon filament, and as a reflector and shield.

1882. O. G. PRITCHARD. **3655.**

Improvements in Electric Lamps.—(Provisional.)

In this lamp the arc is formed between the points of carbons along a narrow and comparatively deep fissure or groove in a piece of marble in which the carbons rest.

1882. H. J. HADDAN. **3814.**

(From C. F. BRUSH.)

Improvements in Electric Lamp Apparatus.

In combination with a "horse-shoe" filament of a screen between the limbs of the filament.

1882. W. CROOKES. 4238.

Improvements in the Manufacture of Incandescent Lamps, and in Apparatus therefor.

Filaments are prepared by fixing a thread on a frame of copper; this is then immersed in a bath of cupro-ammonia to impart to the thread a horn-like texture; the thread is then dipped in acid, and then washed with water whilst on the frame. The thread is then taken from the frame and placed round a rod of glass, in order to give it the desired shape. The ends of the thread are allowed to hang to dry and harden. The thread is then taken off and placed in a carbonising box. After carbonising, the filament is immersed for some time in chloroform, chloride of carbon, or some other analogous liquid, to displace the occluded gas from the pores.

1882. J. F. PHILLIPS. 4676.
(From C. H. F. MÜLLER.)

Improvements in Incandescent Electric Lamps, and in the Preparation of the Carbon Filaments therefor.

Describes filaments made in the shape of a double spiral, the windings of which cross one another.

Also describes a process of impregnating vegetable fibres in a vacuum with a solution of hydrate of carbon in water.

1882. R. KENNEDY. 4752.

Intensifying Fluorescent or Phosphorescent Electric Lighting, whereby the same is rendered serviceable for Illuminating Purposes, and Apparatus for Effecting the said Intensification.

Relates to the coating of the electrodes with substances which become fluorescent in a vacuum when high-tension currents are used.

Also describes an inductorium with a revolving core having extended poles at each end.

1882. E. MÜLLER. 4824.

An Improvement in the Construction of Incandescent Lamps used for the purposes of Electric Lighting, and to be known as "The Patent Bar and Tubeless Incandescent Lamp."—(Provisional.)

A bar of carbonised wood is substituted for the filaments; this is contained in a glass tube with the ends sealed and conductors passing through same.

1882. P. RAOUL DE FAUCHEUX D'HUMY. 4883.

Improvements in Electric Lamps.

Relates to a method for preventing the destruction of the carbons for a considerable period, and also to obviate the necessity of employing a vacuum by the continued production of an atmosphere of hydro-carbon within the lamp.

1882. H. H. LAKE. 5050.

(From S. F. VAN CHOATE.)

Improvements in and relating to Electric Lighting Apparatus, which Improvements are partly applicable for other purposes.

The light-emitting electrode composed of copper, arsenic, and chloride of sodium, in combination with platinum.

Various devices for switching and actuating one of the electrodes, also a number of shunting devices, are described.

1882. E. P. CHAIMSONOVITZ. 5332.

Improvements in the Production of Light and Heat, and Apparatus therefor.

Describes the use of liquid hydro-carbon substances for aiding and intensifying the action of lamps which give light by the agency of electricity.

1882. J. JAMESON. 5346.

Improvements in Incandescent Electric Lamps.

Relates to the supplying to an incandescent lamp during the time of its use of a hydro-carbon fluid gas or vapour, so as to compensate for or make up the loss due to its incandescence.

1882. A. SWAN. 5504.

Improvements in the Manufacture of Incandescent Electric Lamps.

During the manufacture of the glass around the terminal wires a current is made to pass through them, in order to give a more complete adhesion between the glass and the terminal wires.

1882. N. K. CHERRILL. 5566.

Improvements in Exhausting the Bulbs of Incandescent Electric Lamps or other Articles.

Describes method of creating a vacuum in the globes by placing or forming therein a gas, which is drawn or passed therefrom into, over, or through a substance with which it will combine and leave behind it a vacuum in the globe.

1882. J. WAVISH and J. WARNER. 5833.

Improvements in Incandescent Electric Lamps.—(Provisional.)

Provides the globes of incandescent lamps with a screwed ring or collared piece, through which the terminal wires pass, the object being to prevent the rupture of the glass stems.

1883. F. J. CHEESBROUGH. 6.

(From E. R. KNOWLES.)

Improvements in Incandescent Electric Lamps.

Relates to details of fixing the filament to electrodes by cement specially prepared. Also method of sealing the chamber of the lamp.

1883. J. R. H. WILLIAMSON and E. BÖHM. **46.**

Improvements in the Manufacture of Incandescent Electric Lamps.

The electrodes or platinum wire are connected to a T-shaped glass piece inside the globe.

1883. T. E. GATEHOUSE and H. ALABASTER. **180.**

Improvements in Incandescent Electric Lamps.

Constructs continuous conducting filaments, without mechanical joint, from one outside terminal to the other. Also relates to covering their terminals with a metallic sheath.

1883. J. COOPER. **397.**

Improvements in Means and Apparatus for Electric Lighting.—(Provisional.)

In this lamp a vacuum is not required, the resisting material, which becomes incandescent, consisting of a tube of alumina; this tube is filled with carbon closely packed. The air is prevented from coming into contact with the carbon by means of the surrounding coating of alumina, the carbon being unconsumed and rendered lasting.

1883. A. M. CLARK. **631.**

(From — Kabath.)

See Lighting Railway Trains, &c.

1883. O. E. WOODHOUSE, F. L. RAWSON, and W. H. COFFIN. **871.**

Improvements in Incandescent Lamps and in Apparatus employed in conjunction therewith.

Relates to a special form of electric lamp particularly adapted for surgical, microscopical, and other scientific purposes.

1883. J. IMRAY. **1440.**

(From G. Mangin and C. A. Le Royer.)

A New or Improved Electric Safety Lamp.—(Provisional.)

Relates to lamp for use in an atmosphere of combustible gas, and is constructed with an incandescent lamp suspended within a strong glass cylinder containing water, the cylinder being held between a top and bottom plate by springs.

1883. J. L. HUBER. **1646.**

Improvements in the Construction of Incandescent Electric Lamps, and in the Fittings employed therein.—(Provisional.)

Relates to method of fixing terminal wires in lamps.

1883. H. EDMUNDS, Jun. **1812.**

Improvements in Electric Lamps and in the Electric Circuit Connections and Devices for the same.

Relates to various methods for holding and securing incandescent lamps

and also to the adaptation of small incandescent lamps to porcelain or other imitation candles.

1883. J. W. SWAN. **1832.**

Improvements in Incandescent Electric Lamps.

Describes method of depositing copper on the platinum conductors, so as to strengthen them and facilitate the making a firm attachment.

1883. L. G. B. ARRIGHI. **2152.**

Improvements in Incandescent Electric Lamps.—(Provisional.)

Employs filament in the shape of a helix, the upper extremity being turned downward through the centre of the helix to lead it to the conductor. Also relates to a means of sealing the glass bulb.

1883. J. WARNER. **2369.**

Improvements in Incandescent Electric Lamps.—(Provisional.)

Relates to the construction of a globe with the neck arranged to receive a vulcanite plug and rubber washer. The conducting wires are fitted into the vulcanite plug.

1883. J. H. GUEST. **2438.**

Improvements in the Manufacture of Incandescent Electric Lamps, and in Apparatus therewith connected.

Relates to a means of removing atmospheric air from the glass globe containing the filament and sealing the glass without the use of a vacuum pump.

1883. C. H. STEARN. **2978.**

Improvements in the Means employed for Creating a Vacuum in the Bulbs of Incandescent Electric Lamps.

Describes a method in which the bulb wherein the vacuum is to be created is enclosed in a box made of asbestos, and is connected to the exhaustion apparatus. During the final exhaustion a current of electricity is passed through the filament. The box retains the heat, so that the bulb rapidly acquires and retains a high temperature during the final exhaustion, which enables a very high and perfect permanent vacuum to be created in the bulb.

1883. R. HARRISON. **3100.**

Improvements in Incandescent Electric Lamps.

Relates to a method of forming the neck of the bulb and sealing into it metallic L-shaped pieces for connecting to the carbon filament.

Also relates to carbonising the filament while it is united to an iron staple in a closed vessel containing fluid to prevent oxidation.

1883. **H. J. HADDAN.** 3167.

(From R. H. S. THOMPSON.)

Improvements in Incandescent Electric Lamps, and in the Mode and Means of Regulating the Illuminating Power thereof.

The illuminating power of lamps is varied by increasing or diminishing the extent of filament or loop through which the current passes.

1883. **A. SWAN.** 3910.

Improvements in the Manufacture of Incandescent Electric Lamps.

Relates to method of fixing the terminal wires in the globes.

1883. **J. W. SWAN.** 4381.

Improvements in Electric Lamps.—(Provisional.)

Relates to the subjecting of the platinum wire used in the construction of lamps to a treatment which will effect the removal from it of atmospheric air.

1883. **R. BARLOW.** 4573.

Improvements in Portable Electric Lamps, partially applicable to other purposes.

Describes the combination of an incandescent lamp, on a suitable support, with a battery contained in the base of the lamp.

1883. **A. SWAN.** 5158.

Improvements in Incandescent Electric Lamps and their Holders or Supports.

Relates to providing grooves at or about the neck of the globe of the lamp, so that the springs of the holder will engage in the grooves.

1883. **A. M. CLARK.** 5714.

(From G. TROUVÉ.)

Improvements in Electric Lighting Apparatus to be affixed to the Forehead or other part, for use in certain Surgical Operations and other purposes.

Consists of an incandescent lamp mounted in a casing, provided with a reflector and lens, and connected by means of a ball-and-socket universal joint to a frontal plate.

1883. **S. Z. DE FERRANTI.** 5927.

Improvements in the Manufacture of Incandescent Electric Lamps, and in Vacuum Pumps suitable for being used in their Manufacture.—(Provisional.)

Relates to sealing the conducting wires in the globes; also to using spiral filament; also to heating the filament in a hydro-carbon fluid in order to deposit carbon on it to make an efficient connection with the conducting wires.

1883. **D. ZANNI and A. SHIPPEY.** 5955.

Improvements in and relating to the Manufacture of Carbon Filaments or Conductors, and Globes or Bulbs for Incandescent Electric Lamps.

Uses filaments made from straw, felt, moss, or other suitable material.

The material is first reduced to pulp; sugar is added and well mixed; it is then made in flat sheets and cut into strips; the strips are then carbonised.

Relates also to making the glass globes with dioptric sections or spiral ribs; also to an additional globe or glass covering surrounding the lamp globe; also globes made with an upper section of opaque or coloured glass, and the lower section of clear glass.

1884. W. E. DEBENHAM. 10.

Improvements in Electric Lamps emitting Light in a Vacuum.—(Provisional.)

Relates to method of completing the exhaustion of the globe whilst the whole is raised to a great heat, in order to get rid of occluded gases from the metallic and carbon conductors.

1884. J. H. GARDINER. 234.

Improvements in the Manufacture of Incandescent Lamps.—(Provisional.)

Relates to the construction of a lamp with a helical filament, and constructing the ends of the filament with metal terminals, then passing them in the glass globe on opposite sides.

1884. T. COAD. 806.

Improvements in Electric Safety Lamps.—(Provisional.)

Describes the combination of an incandescent lamp and battery for use in mines.

1884. J. SWINBURNE. 1178.

Improvements in the Manufacture of Incandescent Electric Lamps, or Glow Lamps. (Provisional.)

Relates to the making of the connection between the filament and the conducting wires by means of a butt, cross, or lap joint, or made by means of a small carbon sleeve hardened on by short-circuiting in carbonaceous gas or vapour.

1884. J. G. LORRAIN. 1548.

Improvements in Globes for Incandescent Electric Lamps.—(Provisional.)

The globe is made partly of clear or translucent and partly of metallic or granitic glass.

1884. J. G. W. ALDRIDGE. 1799.

A Compound Self-sustaining Filament for Incandescent Lamps.

The filament is hollow, and is formed from a mixture of cellulose or from rag pulp, in combination with salts of tungsten and soda; the ends of the filaments are connected to the upper ends of brass or copper tubes; the lower ends of these tubes are connected by cotton wicks with reservoirs of oil, which, being vaporised by the heat of the tubes, is conveyed in a gaseous state to the interior of the filament and deposited in it.

1884. C. H. BENTON and H. H. GRUBBE. **4208.**

Improvements in the Manufacture of certain Parts of Incandescent Electric Lamps. (Provisional.)

Describes the manufacture of a filament of vegetable fibre and subjecting same to a process of immersion in acid solution, washing, drawing through a die, and carbonising, and then subjecting the filament to a process for depositing carbon on it. Also relates to method of making joints between the filament and the conducting wires.

1884. J. S. FAIRFAX. **4937.**

Improvements in Incandescent Lamps.

Relates to a lamp in which the glass is made of a parallel tube, the filament being attached at each end of the tube.

1884. G. HOOKHAM. **7534.**

Improvements in Incandescent Electric Lamps and in Glasses therefor.—(Provisional.)

Describes methods of obtaining diffusion of light by the use of an incandescent lamp of cylindrical shape and having long filaments, and by the use of a lamp glass which slides over the tube, and which has either convex ribs or concave grooves, such grooves or ribs running parallel to the long filament.

1884. H. H. LAKE. **9649.**
(From N. S. WHITE.)

Improvements in and relating to Incandescent Electric Lamps.

Relates to the combination with the carbon filament of a burner of metal, and adapted to be heated by the carbon. Also relates to the use of a wire gauze envelope for globe.

1884. C. D. ABEL. **11115.**
(From Messrs. SIEMENS & HALSKE.)

Improved Means of Connecting the Carbon Filaments of Incandescent Electric Lamps to their Conducting Wires.

The ends of the platinum conducting wires which pass through the glass stem are hammered flat, and are helically coiled round the ends of the carbon filament.

1884. B. J. B. MILLS. **11145.**
(From W. HOLZER.)

Improvements relating to the Manufacture of Incandescing Electric Lamps.

Relates to a method of straightening a loop form conductor for incandescing lamps, or of changing its shape by subjecting the conductor to strain while raised to incandescence in a vacuum.

1885. J. HARRISON. **3616.**

Application of the Electrical Light to Gymnastic Appurtenances.

Application of an incandescent lamp to a club for stage or other effects.

1885. G. DAVIDSON, R. C. JACKSON, and J. B. DUNCAN. **3765.**

Improvements in the Manufacture of Filaments or Carbons for Incandescent Electric Lamps.

Relates to method of cutting up the material used for filaments.

1885. C. A. DAY. **7321.**

(From F. SCHAEFER.)

Improvements in Carbonising Filaments for Electric Lamps, and in the Apparatus connected therewith.

Describes a yielding carbonisable "former" on which the thread is wound, the "former" yielding in the carbonising process, thus obviating the breaking of the filaments.

SUBDIVISION III.

STORAGE BATTERIES.

1882. J. H. JOHNSON. **1173.**

(From A. DE MÉRITENS.)

Improvements in Secondary Batteries or Electric Accumulators.—(Provisional.)

Mounted lead plates in wood frames, the edges of the frames being fitted with rubber. A number of these frames are bolted together to form the battery, the spaces between the plates being filled with acid and water.

1882. J. S. WILLIAMS. **1174.**

See Subdivision of the Current.

1882. F. MAXWELL-LYTE. **1363.**

Improvements in Secondary Batteries.

Spongy metallic lead plates are formed by taking insoluble or only slightly soluble salts of lead and casting same into moulds. These moulds are reduced to the metallic state by being placed at the cathode of any suitable electric generator.

1882. G. MOLLOY. **1455.**

Improvements in Secondary Batteries for the Storage of Electricity.—(Provisional.)

Several plates of thin sheet lead, closely corrugated, are fitted into wood frames; the frames are placed side by side in a box which is lined with lead; the corrugations in the plates are filled with red oxide of lead.

1882. W. B. BRAIN. 1548.

Improvements in Secondary Batteries.

The plates are made in the form of chambers, bags, or closed envelopes of thin sheet lead, in which is enclosed the oxidising and deoxidising agent, one set of holes being forced through from one side, and another set of holes forced through from the other side.

1882. A. TRIBE. 1587.

Improvements in Secondary Batteries.

Employs a negative plate consisting of peroxide of lead in a solidified form. The positive plate employed may be of any suitable element.

1882. J. H. JOHNSON. 1769.
(From C. A. Faure.)

Improvements in Secondary Batteries.

Construction of tanks or vessels for containing the electrodes.

1882. D. G. FITZGERALD, C. H. W. BIGGS, and W. W. BEAUMONT. 1875.

Improvements in Secondary Batteries.

Describes porous lead electrodes made by electro-depositing lead in a loosely coherent or crystalline form, partially oxidising the same, and then compressing the mass into cakes or plates of any suitable form.

1882. C. V. BOYS. 1946.

Improvements in the Construction of Secondary Batteries.

Describes method of producing finely-divided lead, as follows:—Melt lead and pour it in a suitable receptacle, and gently move it until it begins to granulate; the receptacle is then violently shaken and reduced to a fine powder; it is then sifted and spread in layers on metallic plates or other supports.

1882. C. H. CATHCART and C. B. G. COLE. 2068.

A New or Improved Secondary Battery.

Employs a plate or surface formed of electrolytically deposited and amalgamated pure zinc in combination with a plate or surface of oxide of lead, both being immersed in a solution of zinc sulphate acidulated with sulphuric acid.

1882. T. CUTTRISS. 2135.
(From C. Cuttriss.)

An Improved Process for Forming or Preparing Lead, in the Shape of Plates or otherwise, for Secondary Batteries or Magazines of Electricity, and an Improved Construction of Battery.

Prepares lead plates by means of sulphuric acid, nitric acid, and chromic acid, and connecting them to the positive pole of a galvanic battery.

1882. A. TRIBE. 2263.

Improvements in Secondary Batteries.

Employs metal plate for supports of negative elements which have been to a greater or lesser extent converted into sulphides, arsenides, oxides, phosphides, or other compounds not easily acted upon by electrolytic action.

Uses finely-divided lead, compressed, as positive plate.

1882. J. PITKIN. 2391.

Improvements in the Construction of Secondary Batteries, applicable also to Primary Batteries.

Improvements to Patent 5451, 1881.

A frame consisting of enclosing surfaces formed of louvre-like strips or laths of ebonite or other material, and being placed obliquely; two frames placed so that the laths incline inwardly; between the laths lead turnings are placed.

1882. H. H. LAKE. 2409.

(From H. LORY.)

Improvements in Electric Accumulators or Secondary Batteries.—(Provisional.)

Lead plates are used as electrodes, and the space between the same is divided in two equal parts by a porous partition; the two compartments are filled with lead turnings, shavings, &c.

1882. C. W. VINCENT. 2491.

(Partly communicated by W. B. F. ELPHINSTONE.)

Improvements in Secondary Batteries.—(Provisional.)

In this arrangement lead in solution is preferably employed, as it contains a large quantity of occluded or nascent hydrogen. The lead may be deposited in a finely-divided state either by electrolysis or by chemical process.

Employs also a combination of finely-divided lead with carbon.

Employs pyrophoric lead, which, after compression, is converted into the hydride of lead.

1882. J. S. WILLIAMS. 2558.

Improvements in and relating to the Generation, Storage, Distribution, Regulation, and Utilisation of Electricity, and Apparatus therefor, &c.

System or apparatus described for distributing and utilising electricity for lighting and other purposes, by means of generators, storage batteries, &c.

Describes also lead and carbon, combined, used in storage batteries.

1882. H. WOODWARD. 2643.

Improvement in the Arrangement and Construction of Secondary Batteries, &c.
(Provisional.)

Plates in form of beehive, with corrugated or fluted sides.

1882. A. MUIRHEAD. 2658.

Improvements in the Manufacture of Secondary Batteries.

Lead plates prepared or formed by placing the plates in a vat through which a stream of solution containing lead is caused to flow, and then producing deposits upon the plates by electrolysis.

1882. W. B. BRAIN. 2659.

Improvements in Primary and Secondary Batteries, &c.—(Void.)

Increases efficiency of electrodes by subjecting them to considerable pressure before or after the preliminary charging operation.

1882. A. P. PRICE. 2722.

Improvements in Secondary Batteries.

The negative element of peroxide of lead, also the positive element of metallic lead, is encased or otherwise protected by or in spongy india-rubber.

1882. L. EPSTEIN. 2807.

Improvements in Secondary Batteries.

Employs permanganate of potash, or other permanganate, or permanganic acid, as an oxidising agent.

1882. R. H. WOODLEY and H. F. JOEL. 3221.

Improvements in Secondary Batteries or Accumulators.—(Provisional.)

Electrodes formed of lead wool.

1882. T. S. SARNEY and J. M. ALPROVIDGE. 3240.

Improvements in the Manufacture and Preparation of Plates for Electric Accumulators.

Uses plates of thin laminated metallic sheets impregnated with lead or other metallic oxides, peroxides, or sulphates.

1882. G. L. WINCH. 3532.

Improvements in Secondary or Polarisation Batteries for the Storage of Electric Energy.

Use in secondary batteries of cork or pith on the sides of the plates, salts of aluminum and double salts of alum, either separately or in conjunction with sulphate of copper or sulphate of zinc, with plates of lead and copper, lead and zinc, and lead.

1882. F. J. BOLTON. 3592

Improvements in Secondary Batteries.

Encloses secondary cells in an air-tight casing, so that there shall be no escape for the gases evolved, the pressure of such gases increasing the action of the battery.

Also describes various methods of p ɛparing the plates by mixing chloride or oxychloride of lead with an oxide ot lead, and reducing this mixture by means of zinc.

1882. H. T. BARNETT. **3964.**

Improvements in Secondary or Storage Batteries and in Apparatus connected therewith.

Uses finely-divided lead and felt asbestos in alternate layers.

Also describes the use of an automatic electrode which breaks the charging circuit, so as to cut the accumulator out when charged.

1882. W. A. BARLOW. **4299.**

(From L. ENCAUSSE and Mons. CANÉSIE.)

Improvements in Accumulators or Secondary Batteries.

The electrodes are made of tubes or sheets separated by an insulating body, the plates being surrounded on all sides with a sea salt or chloride of sodium. The cells do not contain any liquid, and are called by the inventors a dry accumulator.

1882. C. T. KINGSETT. **4735.**

Improvements in Secondary Batteries.

Describes the use of a solution of hydrates or salts of alkalies as electrolytes in conjunction with the positive and negative plates.

Also of a positive electrode of iron coated with lead, or with magnetic oxide of iron, in contact with a proto-compound of lead, and a negative electrode of carbon coated with peroxide of lead.

1883. H. J. HADDAN. **317.**

(From E. BOETTCHER.)

Improvements in Secondary or Storage Batteries.

Relates to the charging of a secondary cell with a solution of pure sulphate of zinc, and forming the positive electrode by sending a current through thin sheet zinc or lead dipping into this solution; the negative plate being formed by sending a current through thin sheet lead coated with porous lead and dipping in the same solution.

1883. A. L. NOLF. **482.**

Improvements in the Construction or Formation of a Secondary Battery or Accumulator of Electricity.—(Provisional.)

Employs a spongy lead plate as one electrode, used in conjunction with an ˌlectrode made from a mixture of pure minium and spongy lead and charcoal; the liquid employed is a solution of caustic soda.

1883. A. M. CLARK. **631.**

(From — KABATH.)

See Lighting Railway Trains, &c.

1883. J. H. JOHNSON. **632.**

(From J. A. MALONEY.)

Improvements in Storage Batteries or Electric Accumulators.—(Provisional.)

Describes the use of one plate of black oxide of manganese, and another of carbon, in a liquid in which an ammoniacal substance is held in solution.

1883. W. CROSS. **633.**

Improvements in the Manufacture of Finely-divided Lead, Lead Alloys, and Compounds of the same, for use in Secondary Batteries, &c.—(Provisional.)

Molten lead, after passing through an aperture, is acted on by a blast of any suitable liquid or gaseous fluid; by this means the lead is broken up and separated into a finely-divided condition, which, when coated with oxide, is ussd as an electrode.

1883. T. ROWAN. **791.**

Improvements in Secondary or Storage Batteries.

Relates to a form of battery in which a box is divided into a number of cells or chambers, the cells being filled with granulated lead mixed with peroxide of lead.

1883. O. J. LODGE and J. S. PATTINSON. **927.**

Improvements in Secondary Batteries, and in Renovating or Revivifying their Plates.

Describes the employment of ammonia, acetate, or other solution, for the purpose of cleansing old or sulphated negative lead plates from a crust of sulphate, the pores left in the lead being subsequently filled up by the addition of fresh litharge, or by electrolysing acetate of lead and depositing the lead upon the plates.

Also relates to the employment of amalgamated zinc as an electrolytic deposit in and upon the negative plates, the zinc and mercury being deposited out of a salt of zinc and a salt of mercury.

1883. R. H. COURTENAY. **1016.**

Improvements in Electric Secondary or Storage Batteries.—(Provisional.)

Relates to arranging the cells so as to prevent or lessen the leakage of the current when the cells are not in use.

Relates also to charging the cells with oxygen gas, thus enabling the cells to be charged in much less time than ordinarily.

1883. D. G. FITZGERALD. **1122.**

Improvements in Secondary Batteries or Accumulators.

Relates to the manufacture of indestructible electrodes, or of electrodes which will last for an indefinite period, by the use of any suitable impervious and insulating materials, with which the electrode or the supporting plate backing is in part coated, prepared, or saturated.

1883. G. BINSWANGER and T. SEXTON. 1969.

Improvements in the Construction of Receptacles for Secondary Batteries or Electrical Accumulators.—(Provisional.)

Describes wood boxes or chambers constructed with the sides grooved and made fluid-tight, the grooves being filled with red lead cement.

1883. F. T. WILLIAMS and J. C. HOWELL. 2573.

Improvements in the Manufacture of Porous or Spongy Plates, particularly applicable for use in Secondary Batteries or Accumulators, and also for other purposes.

Employs electrodes constructed as follows:—A mixture of lead and crystallised lead in a molten state is poured in a ladle or mould with a perforated bottom, the liquid metal being allowed to drain through the perforations, leaving the ladle or mould more or less filled by a block of crystalline or spongy lead.

1883. W. R. LAKE. 3340.
(From C. DION.)

Improvements in and relating to Electrical Accumulators or Secondary Batteries, which Improvements are partly applicable to other Batteries.—(Provisional.)

A porous vase is placed between plates of carbon which are immersed in a solution of proto-chloride of iron, the porous vase containing a piece of amalgamated zinc in a solution of chloride of zinc.

1883. A. J. JARMAN. 3886.

Improvements in Storage or Secondary Batteries.

Employs a series of concentric cylinders of lead or lead and silver alloy plates, which are placed in a vessel, and between the plates is packed spun glass or toy beads or sulphured wool, for the purpose of separating the plates; or layers of amorphous lead may be used.

1883. R. H. COURTENAY. 4037.

Improvements in Electric Secondary or Storage Batteries.—(Provisional.)

To prevent leakage the positive and negative electrodes are placed in separate cells.

1883. D. G. FITZGERALD and T. J. JONES. 4197.

Improvements in Secondary Batteries.—(Provisional.)

Describes the construction of portions of the anode element of an alloy of platinum and lead in certain proportions, and which will resist the effects of certain local action which takes place in cells.

1883. G. F. REDFERN. 4612.
(From D. LONTIN.)

Improvements in Electric Accumulators.—(Provisional.)

Relates to the decomposition of alkaline salts by a current in which several sheets of lead are opposed to sheets of amalgamated zinc and placed in an

alkaline solution. When the current is passed the alkaline metal will deposit in the mercury of the amalgamated zinc, and its oxygen will be carried to the lead and will form a peroxide of lead.

1883. W. P. THOMPSON. **5043.**
(From K. W. Zenger.)

Improvements in Electrical Accumulators, applicable in part to Regenerative Primary Batteries.—(Provisional.)

Relates to surrounding positive pole plates (cathodes) with some halogen, such as chlorine, bromine, or iodine; these halogens having a depolarising action, and combining themselves, as soon as both poles are connected by means of a conductor, with the hydrogen surrounding the negative pole plate (anode).

1883. J. S. SELLON. **5069.**

Improvements in Secondary Batteries or Electrical Accumulators.

Relates to providing plates of suitable construction with grooves or overlappings at or round the edges, and containing an insulating material to arrest electrical action or leakage by moisture or capillary attraction.

1883. A. KHOTINSKY. **5540.**

Improvements in Secondary Voltaic Batteries.

Relates to constructing a cell in the form of a shallow trough divided by low zigzag partition into two compartments having branches interspaced with one another, each compartment containing a sheet or shallow layer of one of the elements, and both being covered over with the exciting liquid.

1883. J. GREENWOOD. **5680.**

Improvements in Accumulators for Storing Electrical Energy, applicable also to Primary Batteries.—(Provisional.)

Relates to the charging of accumulators under atmospheric pressure, and by means of which they can be charged in much less time than ordinarily.

1883. J. S. SELLON. **5741.**

Improvements in Secondary Batteries or Electrical Accumulators.

Relates to the employment of strips, plugs, or discs of insulite or porous clay to keep the plates apart, in combination with a binding device capable of yielding under pressure.

1884. G. G. ANDRÉ. **1100.**

Improvements in Primo-Secondary Batteries, or Batteries which partake of the nature of Primary and Secondary Batteries.—(Provisional.)

Relates to the construction of a portable battery, each cell consisting of a core of lead placed in the middle of a tube of lead; the space between the tube and the core is filled with peroxide of lead and granulated carbon.

1884. A. TRIBE. **2073.**

Improvements in or connected with Primary and Secondary Batteries.—(Provisional.)

Describes the construction of retainers or supports for the active elements of nitro-cellulose or gun cotton.

1885. C. S. BRADLEY. **2463.**

Improvements in Secondary Electric Batteries or Electric Accumulators.

Describes the use of an electrolyte of a solution of metallic bromide, which is deposited when the battery is charged, the metal being deposited upon one electrode and the bromine being set free on the other electrode, the bromine thus liberated being taken up by the solution.

1884. G. PRESCOTT, M. F. PURCELL, D. SHERLOCK, and W. H. DUNNE. **5409.**

Improvements in Secondary Batteries.—(Provisional.)

Relates to making the negative plate or anode of suboxide in connection with metallic lead; also for the positive plate the use of lead and oxides in a fine state of mechanical division; also to the construction of the cells with a porous partition between the plates.

1885. J. PITKIN. **3260.**

Improvements in Secondary Batteries or Accumulators.

Describes method of combining with conductive plates several perforated plates of non-conducting material, the active material being held against the conducting plates by the non-conducting plates.

1884. F. G. HOWARD. **9843.**

Frames for Electrodes in Secondary Batteries.—(Provisional.)

Describes the construction and use of ribbed wooden partitions between the plates or electrodes when arranged in a horizontal position.

1884. C. MOSELEY. **10207.**

Improvements in Secondary Voltaic Batteries, applicable also to Single Fluid Primary Batteries.—(Provisional).

Describes the use of separators between the plates, and which are constructed of any suitable material, such as gutta-percha, celluloid, or hard vulcanised rubber.

1884. E. G. DORNBUSCH. **11853.**

Improvements in Secondary Batteries.

Relates to the use of felt or flannel as a support for the active material.

1884. D. G. FITZGERALD. **12350.**

Improvements in Secondary Batteries or Accumulators.

Relates to the use of anodes and cathodes of lead in combination with an

electrolyte consisting of sulphate of magnesia in solution, or of an electrolyte containing this salt in sufficient quantity to enable the process of "forming" and "charging" to be effected by two passages of the current in opposite directions.

1884. A. H. REED. 14508.

(From E. COMMELIN and G. BAILHACHE.)

Improvements in Secondary Batteries.

Employs zinc plates as electrodes. These are placed in a solution prepared by dissolving oxide of zinc in potash or soda, or any other oxide of metal soluble in these alkalies.

SUBDIVISION IV.

ELECTRODES.

I.—FOR ARC LAMPS.

1882. A. SMITH. 1465.

Improvements in Carbons for Electric Lamps.

Passes through the liquid furfurol or fucusol hydrochloric acid gas; the black liquid produced is pressed between glass plates; the material is then cut in narrow strips and exposed to boiling heat, and then placed in carbon powder and exposed to a high heat.

For rod carbons the same operation is performed, except that the carbon is formed in a tube before it is exposed to the high heat.

1882. A. S. CHURCH. 1822.

(From J. B. KING.)

Improvements in Electric Lamps.

The introduction of moist atmospheric air through the centre of the carbons, which are also arranged with a spiral conductor in the centre of the carbons.

1882. F. H. VARLEY. 2776.

Improvements in Manufacturing Carbons, applicable for Electric Candles, Poles Battery Plates, and Accumulators.

Calcined vegetable fibres saturated with a hydro-carbon substance, or fluid saturated into rope or string, and carbonising same.

1882. R. WERDERMANN. **3757.**

Improvements in the Manufacture of Light-emitting Conductors for Electric Lighting purposes, and in Apparatus therefor, which Apparatus is also applicable for other purposes.

Uses, instead of carbon, cystallised silicium or "graphitoidal silicium."

1882. H. J. MARSHALL. **4168.**

A Process for the Carbonisation and Preparation of a Material for Electrodes for Arc or Incandescent Lamps.—(Provisional.)

Proposes to use carbonised cane.

1882. R. HAMMOND and L. GOLDENBERG. **4344.**

Improvements in Electric Lamp Carbons, and in the Manufacture thereof. (Provisional.)

Employs carbons composed of plumbago or other carbon reduced to a fine powder and mixed with the powder of another substance which is fusible by the heat of the arc..

1882. H. C. BRADLEY. **5353.**

Improvements in the Manufacture of Carbons for Electric Lighting.

Moss peat or bog peat is dried and calcined in closed vessels at a high temperature; to this is added syrup of sugar, starch, rice, and gum, and made into a paste; it is then compressed into a mould, and carbonised in closed vessels.

1882. J. E. T. WOOD. **5400.**

Improvements in Carbons for use in Electric Lamps and for other purposes.

Describes carbon electrodes in which wires of aluminum, magnesium, or other suitable metal, are placed in the centre and form a core.

1883. W. HOUGHTON. **1911.**

Improvement in the Manufacture of Electrodes for Arc and Incandescent Lamps. (Provisional.)

Relates to the manufacture of electrodes of carbon in its allotropic form as it exists in the diamond, diamondiferous ore or matter. The substances or products are known as "eolite," "boart," and "carbonado," these materials being used separately or together in their natural form, or in powder, or in paste, or mixed with one or more substances to bind same together.

1884. W. HARTNELL. **8781.**

Improvements in and connected with Carbons for Electric Arc Lighting.

Describes methods of joining together the ends of carbon rods, and various dowels and connecting pieces for same.

II.—FOR INCANDESCENT LAMPS.

1882. **F. WRIGHT and M. W. W. MACKIE.** **1274.**

mprovements in Incandescent Electric Lamps.—(Provisional.)

Employs tubular stem for carrying the conducting wires and exhaust tube.

Makes filaments of vegetable fibres free from mineral or inorganic matter, and obtained from any suitable plant specially grown in distilled water, &c.

1882. **A. SMITH.** **1465.**

See Electrodes for Arc Lamps.

1882. **W. H. AKESTER.** **1642.**

Improvements in Incandescent Electric Lamps.

Carbon formed by vegetable fibres being subjected to the action of an extremely concentrated solution of chloride of zinc for about two hours, at a temperature of 120° Fahrenheit; it is then washed and drawn through a die, which hardens it.

Electrodes are brought through glass at the sides instead of the middle at the bottom.

1882. **J. JAMESON.** **1670.**

Improvements in Incandescent Electric Lamps.

Combines a tenacious cement with carbon which is deposited from hydrocarbon gas, the object being to afford freedom and facility of handling, and reducing the material to any desired dimensions.

1882. **A. R. LEASK.** **1803.**

Improvements in the Method or Process of Manufacturing Incandescent Lamps, and in Tools or Apparatus therefor.

Describes method of securing the ends of the filament by means of a platinum helix, and method and apparatus of performing same.

1882. **P. M. JUSTICE.** **1895.**

(From A. Cruto.)

Improvements in and connected with Electric Lighting and Incandescent Lamps.

To obtain carbon filaments heavy carburets of hydrogen or chlorides of carbon are brought into contact with bodies whose surface contains aluminous silicates or alkalines which decompose at the same temperature as the carbon compounds.

An apparatus for automatically regulating the electric current supplied to electric lamps is also described.

1882. **A. L. JOUSSELIN.** **2037.**

Improvements in the Manufacture of Electric Incandescent Lights in the Vacuum. (Provisional.)

Uses carbon filaments made with materials consisting chiefly of cellulose,

and further impregnated in a solution of plastic cellulose, and then washed with water and ammonia; drying, and steeping in a solution of sugar; coating with pure graphite and drying gently, and then put into required shape; further dried at a temperature of 150° C., and carbonised.

1882. J. RAPIEFF. **2136.**

Improvements in Incandescent Electric Lamps.

Describes filament on which is deposited pure metallic or crystalline carbon by heat or by electricity from hydrogenic compounds of carbon with iodine, chlorine, sulphur, selenium, and substances similar in nature.

Uses filaments of spiral or zigzag form.

1882. C. J. ALLPORT. **2192.**

Improvements in, and in the Manufacture of, Bridges or Loops for Incandescent Electric Lamps.

Employs asbestos filaments, carbonised.

1882. S. H. EMMENS. **2348.**

Improvements in Incandescent Electric Lamps.

Carbonised ivory filament, flat disc perforated, two or more filaments in lamps, and various sockets, &c., are described.

1882. J. WETTER. **2452.**

Improvements in Incandescent Electric Lamps.

Employs filaments made of cellulose or animal parchment impregnated with carbon, &c.

Uses also a cement for fixing the filaments, composed of graphite, spongy platinum, and molasses or sugar.

1882. S. HALLETT. **2560.**

Improvements in and connected with Electric Lamps, and in Electrodes therefor.

Improvements on Patent No. 4017, 1881.

Describes filaments made from cocoa-nut shell; also from pulverous carbonaceous matter prepared with gelatine or glue, and the admixture of tannic acid forming the carbon mass, which is moulded and recarbonised.

1882. F. DES VŒUX. **2604.**

(From A. Bernstein.)

Improvements in the Manufacture of Incandescent Electric Lamps.

In this lamp the light-giving part is composed of a non-conducting and infusible carrier, and of a film or deposit of carbon covering partly or entirely the surface of the carrier.

1882. **J. WETTER.** 2660.

(From W. Stanley, Jun.)

Improvements in Carbon Burners for Electric Lamps.

Carbonised hair used for filament.

1882. **G. ZANNI.** 2741.

Improvements in Illuminating Conductors for Incandescent Electric Lamps.

The light-emitting conductor composed of a wire of platinum or similar metal coated with carbon.

Thread of silk, cotton, or other suitable material, carbonised, then covered with platinum or similar metal, and coated with carbon.

1882. **A. PFANNKUCHE.** 2845.

Improvements in Electric Lamps.—(Provisional.)

The luminous bridge is made hollow, and consists of a hollow plaited or woven fabric made of jute, hemp, cotton, or other suitable material.

1882. **W. E. DEBENHAM.** 3010.

Improvements in Electric Lamps with Incandescent Conductors, and in the Manufacture of the same.

Uses alcoholic solution of gluten for compacting the fibre which is to form the carbon.

1882. **F. S. ISAAC.** 3033.

(From Sir. J. Vogel.)

Improvements in the Production of Carbons for Incandescent Electrical Illumination.

Fibre known as *Rubus Australis, Parsona, Lygodium,* or "Supple Jack," used for filaments.

1882. **I. L. PULVERMACHER.** 3318.

See Electrodes for Storage Batteries.

1882. **J. H. HADDAN.** 3382.

See Lamps—Miscellaneous.

1882. **T. PARKER and P. B. ELWELL.** 3710.

Improvements in Electric Lighting and in Apparatus connected therewith.

Describes filaments for incandescent lamps composed of fibres drawn from the leaves of the greater plantain or waybread (*Plantago major*).

Describes electrodes for storage batteries, prepared by placing the lead plates in a dilute solution of sulphuric acid with a small quantity of nitric acid added.

Describes a form of dynamo-electric machine in which the armature is constructed with bars running parallel with the axis of the machine. The

bars are conneeted in sets of two, their ends being led to the commutator; each set of strips is under the influence of two opposite polar extremities of field electro-magnets.

1882. . G. PFANNKUCHE and A. A. DIXON. **3861.**

Improvements in Electric Incandescent Lamps.—(Provisional.)

Filaments consist of hemp or flax fibres, and after being dried the outer hard skin is removed; it is then cleaned by exposure to an alkaline solution; the fibre is then soaked in a heavy hydro-carbon oil or a saturated solution of sugar and lampblack and gum, and after being shaped is carbonised.

1882. T. J. HANDFORD. **3955.**
(From T. A. Edison.)

Improvements in or relating to Incandescing Electric Lamps and Means connected therewith.

Provides the filaments with enlarged ends of same material as the filament itself, and electro-plating such ends, and then soldering or fusing the ends to the electrodes which pass through the glass.

1882. T. J. HANDFORD. **3991.**
(From T. A. Edison.)

Improvements in the Manufacture of Incandescing Conductors for Electric Lamps.

Describes flexible carbon filaments made from carbonised oxidised drying oil, or carbonised gluten, or a mixture of the same with other carbonisable material.

1882. H. J. MARSHALL. **4168.**
See Electrodes for Arc Lamps.

1882. J. JAMESON. **4180.**

Improvements in the Manufacture of Carbons for Incandescent Electric Lamps.

Prepares carbons by depositing a film of carbon from gas or vapour upon a prepared surface of glazed porcelain, the porcelain being so shaped that the ultimate shape of the filament is produced by the deposit.

1882. W. R. LAKE. **4458.**
(From E. Weston.)

Improvements in the Manufacture of Carbon Conductors for Electric Lamps.

Filaments made by first converting cellulose into celluloid or collodion, then treating it with reducing or deoxidising agents to convert it into non-fibrous or amorphous and homogeneous cellulose, and finally forming therefrom the conducting strips, and carbonising same.

1882. M. BAILEY. **5023.**

Improvements in Carbons for Incandescent Electric Lamps.

The carbon is not made in the form of a filament, but consists of a tubular

shape with a hollow globe in the centre, which is pierced around its circumference.

1882. H. H. LAKE. **5050.**

(From S. F. van Choate.)

See Incandescent—Miscellaneous.

1882. J. M. BOULLON, I. PROBERT, and A. W. SOWARD. **5373.**

Improvements in Electric Lamps or Lighting Apparatus, and in the Manufacture of Light-emitting Conductors for the same.

Filaments constructed by a deposition of carbon or other material from gas or vapour decomposed by the passage of electric sparks through the same.

1882. A. FERGUSSON. **5779.**

Improvements in and connected with Electric Lamps, and in Switches therefor.

Describes filaments made of bass-wood, and twisted or looped before being carbonised.

1882. L. A. GROTH. **6075.**

(From A. Bernstein.)

Improvements in Incandescent Electric Lamps.

Uses a hollow cylindrical carbon, with solid supporting carbon socket.

1882. T. J. HANDFORD. **6193.**

(From T. A. Edison.)

Improvements in and relating to Incandescing Electric Lamps.

Describes the production of a flexible carbon filament by the carbonisation under strain or pressure of any suitable organic material. Also relates to details of fixing the electrodes, &c.

1882. T. J. HANDFORD. **6206.**

(From T. A. Edison.)

Improvements in Incandescing Conductors for Electric Lamps, and in Moulds for the Carbonisation of the same.

The filament is formed of a number of separate continuous filaments, consisting of natural vegetable fibres, secured together, and each capable of independent expansion and contraction.

1883. J. WAVISH and J. WARNER. **39.**

Improvements in Carbons for Incandescent Electric Lamps.

The filament is substituted by a short rod of carbon having thickened ends—*i.e.*, with turned down or reduced central portion; a central hole penetrates the carbon lengthwise, and is also perforated transversely.

1883. G. BOWRON and W. HIBBERT. 764.

Improvements in the Manufacture of Carbon Filaments for Incandescing Electric Lamps.

Describes filaments made from a mixture of carbon in a fine state of division, with a solution of sugar or other viscous liquid of an organic nature.

1883. A. M. CLARK. 1156.

(From J. M. A. GÉRARD-LESCUYER.)

Improvements in Electric Incandescent Lamps.—(Provisional.)

Relates to the arrangement and combination of a pair of straight or curved fine pencils, or of carbon, pressed at their free ends against a block of carbon placed between them, or against one another, so as to effect a certain and renewable contact in case of wear.

1883. W. HOUGHTON. 1911.

See Electrodes for Arc Lamps.

1883. J. S. KELSO. 1275.

Improvements in Electric Lamps.—(Provisional.)

Describes the arrangement of two or more filaments either divided or insulated centrally.

1883. E. LUMLEY. 1684.

Improvements in Electric Lamps or Lighting Apparatus.

Relates to fastening the ends of carbon filament by means of spirals at the ends of conducting wire, and cementing same with lampblack.

1883. E. MÜLLER. 1776.

Improvements in the Construction of Incandescent Electric Lamps.

Employs filament made of boxwood (*Boxus sempervirens*), and describes method of fixing the filament to the conducting wires and sealing same in the glass.

1883. W. CROOKES. 2185.

Improvements in the Manufacture of Incandescent Lamps, and in the Apparatus to be used in connection therewith.

Relates to mounting the filament upon that portion of the lamp to which it is to remain permanently attached, prior to adjusting its resistance, and performing such adjustment by placing the lower portion of the lamp enclosured, with the filament attached, in a chamber in which it is electrically ignited in suitable vapour or gas.

Also describes various kinds of sockets and connections for use with incandescent lamps.

1883. F. WRIGHT and M. W. W. MACKIE. 2198.

Improvements in Incandescent Electric Lamps.—(Provisional.)

Employs filaments made in the form of a double spiral.

1883. W. J. L. HAMILTON. **2850.**

Improvements in the Construction and Manufacture of Electric Incandescent Lamps, and in Appliances for the Regulation of Electric Currents therefor, and for other Electrical purposes.

Employs filaments made of bogwood, such as that from fir, oak, or yew.

Also relates to the impregnation of filaments with spongy platinum, for the purpose of lowering the electrical resistance of same.

Also relates to the regulation and governing of the speed of dynamo-driving engines, and specially the governor solenoid in combination with a variable resistance.

1883. G. F. REDFERN. **3915.**

(From A. BERNSTEIN.)

Improvements in Incandescent Electric Lamps.

Relates to the use of hollow carbons made from paper or textile fabrics knitted or braided.

1883. J SWINBURNE. **5159.**

Improvements in the Manufacture of Incandescent Electric Lamps.—(Provisional.)

Describes filaments made of cotton or linen thread passed through strong nitric acid, then through water, and then boiled in a solution of potassium or ammonium sulphide.

1883. J. WAVISH, J. WARNER, and M. BAILEY. **5325.**

Improvements in Carbons for Incandescent Electric Lamps.

Improvement to Patent 39, 1883.

Relates to making the filaments of a flat helix or flat coiled piece or ribbon.

1883. C. H. F. MÜLLER. **5749.**

Improvements in Manufacturing Carbons for Electric Lamps.—(Provisional.)

Improvements to Patent No. 4676, 1882.

Prefers to use ratten, and to thoroughly impregnate same with liquids which will increase the homogeneity of the material both before and after carbonisation.

1883. J. W. SWAN. **5978.**

Improvements in the Manufacture of Carbons for Incandescent Electric Lamps.

Relates to manufacturing carbon filaments by forcing a mixture or solution of nitro-cellulose in acetic acid through a hole or die in a liquid capable of causing the "setting" of the filament as it issues from the jet.

1883. L. GOLDBERG and A. L. FYFE. **5987.**

Improvements in and appertaining to Incandescent Electric Lamps and their Holders, also in the Switches employed therein.

Describes filaments made from thread, the thread being subjected to a process of carbonisation.

Also refers to method of making connection with the socket.

1884. J. SWINBURNE. **4121.**

Improvements in the Manufacture of Filaments for Incandescent or Glow Lamps.

Relates to coagulating the fibres of cellulose by means of nitric acid.

1884. F. H. VARLEY and R. H. PADBURY. **4781.**

Improvements in Carbon Filaments for Incandescent Electric Lamps.—(Provisional.)

Improvements to Patents Nos. 2776 and 5055, 1882.

Relates to submitting the fibrous material previous to carbonising to treatment in borax and alum.

1884. J. S. WILLIAMS. **12064.**

Incandescent Electric Apparatus and the Manufacture thereof.

Relates to the employment of an indestructible support for the conducting material, and which is also adapted to operate in unison for the development of light.

1884. W. P. THOMPSON. **12127.**

(From O. A. Moses.)

Improvements in Incandescent Electric Lamps.

Relates to construction of lamps in which the filament is formed in the shape of two incomplete circles united with each other; and also relates to method of fixing the conducting wires, &c.

1884. H. WATT. **13133.**

(From E. Weston.)

Improvements in and relating to the Manufacture of Incandescence Electric Lamps.

Gun cotton is dissolved in a solution of camphor and reduced to a condition of celluloid; the mass is then cut up into sheets and treated with sulphide of ammonium, so as to produce a non-structural substance termed "tamadine;" the filaments are then cut from the sheets and placed between sheets of paper, and packed with powdered plumbago in nickel boxes and heated for an hour or two, and then slowly cooled. Vapour of gasoline is deposited on the filament.

1884. J. S. WILLIAMS. **13883.**

Improvements in Incandescent Electric Lamps, and in Apparatus or Means for use in Manufacturing the same.

Relates to the making of filaments by combining a heat-resisting non-conducting material with a conducting material.

1884. F. WYNNE and L. S. POWELL. **16805.**

Improvements in the Production of a Carbonisable Material suitable for the Manufacture of Carbons for Electric Lamps, and in the Manufacture of this Material for this and other purposes to which it is applicable.

Relates to the production of cellulose in solution of iodide of zinc, chloride

of zinc or bismuth, or bromide of zinc or bismuth. Also relates to making the filaments by pressing the solution through squirts.

1885. R. DICK. **3115.**

Improvements in the Manufacture of Filaments for Incandescence Lamps.

Encloses the filaments in copper tubes during manufacture, and after carbonising removes the copper by immersion in nitric acid or by electrolysis.

1886. W. R. LAKE. **1619.**
(From H. S. MAXIM.)

Improvements in the Manufacture of Carbon Conductors for Electric Lamps, and in Apparatus therefor.

A cylinder in which is fitted a plunger is filled with a plastic carbonised compound; when the plunger descends it forces the compound through an aperture in the lower part of the cylinder; the aperture is provided with an enlarging slot so that the ends of the filaments may be larger than the middle of a length. The filament is then subjected to the carbonisation process.

The carbon compound consists of finely-divided graphite or retort carbon, and a cohesive substance such as copal or coal tar.

III.—FOR STORAGE BATTERIES.

1882. F. J. CHEESBROUGH. **2.**
(From E. R. KNOWLES.)

Improvements in Storage Batteries for Accumulating Electricity.

Describes electrodes built up or constructed of alternate plates of lead and oxide of lead.

1882. W. BOGGETT. **2595.**

Improvements in Preparing certain Materials for use in Secondary Electric Batteries.
(Provisional.)

Proposes to jag the surface of plates by means of a tool similar to a rasp used by bakers, the small particles which become detached being used to form electrodes.

1882. SIR CHAS. T. BRIGHT. **2602.**

Improvements in Secondary Batteries or Apparatus for Storing Electricity.

Employs a chamber or cell filled with small spherical lead granules. Covers surface of lead with dioxide of lead by first exposing it to the warm vapours of acetic acid and carbonic acid gas, and afterwards treating it with chlorine gas.

1882. A. M. CLARK. 2676.

(From J. M. A. Gérard-Lescuyer.)

An Improved Process of "Forming" or Preparing Electrodes for Secondary Batteries.

Describes the "formation" of the plates or electrodes by the action of an electric current on an alkaline solution of suitable metallic salts in which the plates or electrodes are immersed preparatory to transferring them to an acid solution to be charged in the ordinary way.

1882. J. S. SELLON. 2818.

Improvements in Secondary Batteries.

Describes the construction of perforated plates having holes of many different shapes, for retaining the material with which the plates are packed.

1882. S. H. EMMENS. 2913.

Improvements in Secondary Batteries.

Electrodes formed of a superposed cylindrical spiral of sheet lead, foil, or wire. Also describes lead discs or rings forming cylinders one within the other.

1882. T. PARKER and P. B. ELWELL. 2917.

See Dynamo- and Magneto-Electro Machines of the Gramme type.

1882. H. ARON. 2943.

Improvements in Primary and Secondary Galvanic Batteries and Cells, and in Materials therefor.

Employs collodium combined with lead oxides formed into plates.

1882. C. SORLEY. 2945.

Improvements in Plates for Secondary or Storage Batteries.

Employs plates of lead with a number of grooves cut or formed so that the ridges between the grooves terminate in thin edges, either rough, toothed, or plain.

1882. A. WATT. 3097.

Improvements in Secondary Batteries.—(Provisional.)

Improvements on Patent 4255, 1881.

An alloy of lead and zinc is poured in a molten condition into water to produce it in a granulated form; it is then formed into slabs by pressure; the slabs are then placed in a solution of salt of lead or dilute acid, whereby the zinc will be removed and be replaced by a deposit of spongy lead.

Also describes using for negative plates, carbon surrounded with granulated peroxide of manganese and granulated carbon.

1882. C. H. CATHCART. 3107.

Improvements in Secondary Batteries

Improvements in Patent 2068, 1882.

Employs positive plates of perforated zinc, amalgamated; negative plates of lead amalgamated with mercury and oxidised by electrolytic action.

1882. H. J. HADDAN. 3108.

(From C. F. BRUSH.)

Improvements in Secondary Batteries or Magazines of Electricity, and in Apparatus connected therewith.

Describes methods for forming electrodes, and systems of distribution and connections, &c.

1882. A. M. CLARK. 3296.

(From G. PLANTÉ.)

An Improvement in Preparing the Sheet Lead Electrodes of Secondary Batteries with a view to their Rapid Formation.

Describes the use of nitric acid for the rapid formation of lead plates, and which is effected by immersing the plates or sheets of lead in nitric acid diluted with from once to twice its volume of water for about twenty-four hours, before submitting them to the action of the primary current.

1882. F. W. DURHAM and P. WARD. 3303.

Improvements in Secondary Voltaic Batteries.

Lead is drawn into the form of pinion wire (*i.e.*, star shape in section); it s then wound crosswise on a rectangular frame.

1882. I. L. PULVERMACHER. 3318.

Improved Means and Appliances or Apparatus for Producing or Evolving, Collecting, Storing, and Utilising Electric Energy for Lighting and for General purposes; partly applicable for use in combination with Coal Gas.

Electrodes are constructed of lead wire wound on a mandril in a spiral forming a cylinder; the interstices of the spirals are filled with oxide of lead.

To increase the brilliancy of gas flame a platinum helix is placed in the flame and an electric current passed through it.

1882. W. TAYLOR and F. KING. 3409.

Improvements in Plates for Secondary Batteries or Accumulators.

Uses plates consisting of strips or tapes of lead with uneven surfaces and coated with red lead or minium, and then coiled up.

1882. J. H. JOHNSON. 3464.

(From J. H. Sutton.)

Improvements in Secondary Batteries or in Apparatus for Storing Electricity. (Provisional.)

Employs cylinders or discs of carbon saturated with an aqueous solution of acetate of lead, then taken and saturated in a solution of sulphuric acid, whereby sulphate of lead in a finely-divided state is formed in the pores of the carbon. The sulphate of lead is reduced to spongy lead on passing a current of electricity through it.

1882. L. H. M. SOMZÉE. 3465.

Improvements in the Accumulation and Distribution of Electricity, and in the Apparatus employed therein.

Describes electrodes formed in the shape of lattice-work, wire cloth, or gauze, or formed of a number of metallic pockets with a retaining grate or net. The metallic oxide is placed in the meshes of the lattice-work or in the pockets or compartments.

Also describes plates constructed of a number of superposed tubes.

1882. C. E. BUELL. 3528.

Improvements in Secondary Batteries or Storage Batteries, and in the Methods of and Means for Charging and Discharging the same.

Uses two cells or compartments separated by a porous partition, and each filled, or nearly filled, with globular or spherical pieces of lead, carbon, or other similar material.

Also describes system of connections for installation, &c.

1882. T. CUTTRISS. 3665.

(From C. Cuttriss.)

Certain Improvements in the Construction of the Plates of Secondary or Electrical Storage Batteries.—(Provisional.)

Electrodes formed by taking a quantity of soda, and, while drying it, incorporating a quantity of the salts or oxides of lead, so that when it becomes a pasty or doughy mass it can be rubbed through a sieve to form granules. The soda can be removed by any suitable treatment, leaving a porous plate.

1882. E. G. BREWER. 3700.

(From O. Schulz.)

Improvements in Secondary Batteries.

Lead electrodes are treated with sulphur for the production of a layer of sulpheret of lead on same, for the purpose of forming a porous surface, on which the power of absorption of oxygen and hydrogen depends.

1882. L. EPSTEIN. 3770.

Improvements in the Preparation of Lead for use in the Cells of Secondary Batteries.

Obtains a spongy preparation of lead by adding permanganate of potash to molten lead.

1882. C. T. KINGSETT. 3802.

Improvements in Secondary Batteries.

Describes electrodes constructed as follows:—A length of lead piping, say ¾-inch bore by 1 foot long, is pierced with holes; a number of these are arranged in a trough, and are filled with a thick paste of glycerine or dilute sulphuric acid and red lead or peroxide of lead.

1882. J. S. BEEMAN, W. TAYLOR, and F. KING 3812.

Improvements in Electric Secondary or Storage Batteries.

The electrodes are formed of ribbons, tapes, strips, and also of powdered carbon, graphite, or other similar material, in combination with salts of lead.

1882. F. MORI. 3822.

Improvements in Batteries for the Storage of Electricity.

Uses electrodes formed of a mixture of lead, binoxide of manganese, and antimony, the plates being cellular or honeycombed, so that they may be easily filled with peroxide or acetate of lead.

1882. H. J. HADDAN. 3893.
(From H. Aron.)

Improvements in Secondary or Storage Batteries.—(Provisional.)

Lead made up in the form of network for electrodes, with a mixture of lead combinations and asbestos, cellulose, horse-hair, wool, &c., and placed in the meshes of the network.

1882. N. C. COOKSON. 3941.

Improvements in Secondary Batteries and in Methods of Constructing the same. (Provisional.)

Lead wire is made by running a continuous stream of entirely melted lead through a perforation at the bottom of a vessel containing water. The cooling solution may be acetic acid, which produces a thin but adherent coating of oxide. The wire thus treated is fitted to a frame to form the electrodes.

1882. T. J. HANDFORD. 3961.
(From T. A. Edison.)

Improvements in Secondary Batteries.

Uses electrodes composed partly or entirely of arborescent metallic lead formed from molten lead.

1882. J. E. T. WOODS. 3975.

Improvements in Secondary Batteries and Electric Accumulators.

Use of asbestos or spun glass as mediums for retaining the metallic oxides.

1882. L. H. M. SOMZEÉ. 4079.

Improvements in Secondary Batteries for the Accumulation of Electricity, and in the Mode of Constructing the same.

Employs electrodes constructed of pulverised coke or a carbonisable organic substance and a first oxide or salt of lead, with acid added; the whole is then heated to carbonise the organic matter and to produce the super-oxidation of the oxide or salt employed.

1882. P. DE VILLIERS. 4148.

Improvements in Apparatus for Generating, Intensifying, and Accumulating or Storing Electrical Energy.

A combination in one machine of a dynamo and storage battery. Uses in the storage battery electrodes composed of carbon in combination with pyrolusite or peroxide of manganese and with sheets of lead, and a mixture of powdered lead and pumice-stone.

1882. D. G. FITZGERALD. 4178.

Improvements in Secondary or Storage Batteries.

Electrodes made of carbon in conjunction with finely-divided lead or an oxide or insoluble salt of lead; also of lead.

1882. T. SLATER. 4266.

Improvements in Storing Electric Energy.—(Provisional.)

Electrodes are made of thin sheets of perforated iron or iron wire gauze upon which is spread a mixture of sulphate of magnesia and caustic soda or potash; the electrodes are separated by a porous partition, or strips of glass.

1882. E. FRANKLAND. 4303.

Improvements in Electrical Storage Batteries.

Describes the hardening a mixture of red lead and dilute sulphuric acid after being spread on the lead plates by drying the same to a steam heat several times. The plates so prepared take a high charge, and their coating becomes harder by use.

1882. F. J. CHEESBROUGH. 4316.
(From A. K. EATON.)

Improvements in Secondary or Storage Batteries for the Accumulation of Electricity.

Employs electrodes made of a skeleton plate formed of thin sheet lead or open wicker-work of lead wire, and upon this is deposited spongy lead. The plates thus prepared are, after being washed, pressed between two sheets of paper or cloth, &c.

1882. F. J. CHEESBROUGH. 4317.
(From A. K. Eaton.)

Improvements in Secondary or Storage Batteries for the Accumulation of Electricity.

Describes an electrode formed of spongy lead encased in a sheathing of cloth or asbestos board. A number of these are placed in a containing vessel, and the spaces between are filled with carbon mixed with a finely-divided metal. The lead plates form one pole, and a plate of copper embedded in the carbon forms the other pole. The solution around the lead plates consists of dilute sulphuric acid, and in the space containing the carbon, of a solution of sulphate of copper or other metallic salt.

1882. W. SINNOCK. 4352.

Improvements in the Manufacture of Electrodes.

The materials constituting the electrodes are moulded with numerous holes.

1882. N. C. COOKSON. 4391.

Improvements in the Preparation of Plates for Secondary Batteries.

Describes lead filaments or wire made by filling a vessel with molten lead and allowing it to issue from very fine perforations at the bottom. When several orifices are arranged at the bottom of the vessel the issuing lead is interlaced, and produces a species of felted fabric; this is consolidated between rolls, and is then attached to sheets of lead.

1882. A. WATT. 4431.

Improvements in Secondary Voltaic Batteries, and in the Manufacture of Material and Plates therefor.

Electrodes are formed of granulated or pulverulent lead by the dispersive action of a jet of fluid on molten lead or alloy, and causing the dispersed metal to be deposited as a coherent sheet on a suitable backing.

1882. A. KHOTINSKY. 4490.

Improvements in Secondary or Accumulator Voltaic Batteries.

Relates to construction of a compound plate by pressing together and surrounding with leaden bands a number of plates of lead or of a carbonised fabric, alternating with layers of spongy lead.

1882. F. M. LYTE. 4525.

Improvements in the Manufacture of Secondary Batteries or Accumulators.

Employs electrodes constructed with a central portion composed of a porous carbon plate or a network of carbon or lead fixed in an external frame of dense carbon or lead. The central portion can be made by carbonising a network of string, fibre, &c.

1882. F. C. HILLS. 4561.

Improvements in Secondary Batteries or Electric Accumulators.

(Void through neglect to file Specification.)

Relates to the use of feathered lead, which is produced by heating lead to such a degree that when it is poured in a regulated stream from a considerable height into water it is brought into a finely-divided state; the lead thus prepared is compressed and placed into frames.

Also prepares plates by making an alloy of lead and zinc and placing them in a salt of lead in solution, the interstices produced being filled up by the lead in the solution.

1882. W. CLARK. 4599.

(From N. DE KABATH.)

Improvements in the Construction of Secondary or Storage Batteries, and in the Preparation of the Spongy Lead to be used therein.—(Provisional.)

Electrodes formed of lead plates pierced with holes or strips interlaced to form a network. Spongy lead is used for coating and filling the above plates.

1882. ST. G. LANE FOX. 4625.

Improvements in Planté's Secondary Batteries and in Apparatus connected with such or other Batteries.

Describes electrodes constructed of a laminæ of lead, separated by sand or porous material and pressed together.

1882. A. F. ST. GEORGE. 4696.

Improvements in Electrical Accumulators or Secondary Batteries.—(Provisional.)

Describes electrodes formed of carbon plates and contained in a porous cell in which is placed chromate of lead made into a paste with water.

1882. A. KHOTINSKY. 4756.

An Improvement in Secondary Voltaic Batteries.

Employs peroxide of lead prepared chemically, placed in or on lead plates, instead of red lead or one of the lower oxides, and then having to subject the element to long-continued electrolytic action to obtain the peroxide.

1882. R. TATHAM and A. HOLLINGS. 4809.

Improvements in Secondary Batteries.

Electrodes constructed of a mixture of vegetable fibre and metal, either in a finely-divided condition or in the form of an oxide or salt.

1882. J. E. LIARDET and T. DONNITHORNE. 4991.

Improvements in Secondary Batteries and in the Manufacture of the same.

Improvements to Patent No. 120, 1882.

Describes electrodes constructed of very thin sheets of pure metallic lead.

Also describes method of preparing the spongy lead which is used on the plates.

1882. A. F. HILLS. 5078.

Improvements in Secondary Batteries, also applicable to Ordinary Galvanic Batteries. (Provisional.)

Perforated lead plates are employed, the spaces being filled with lead oxide; between the plates a suitable electrolyte is placed.

1882. R. HAMMOND and L. GOLDENBERG. 5097.

Improvements in Secondary Batteries.—(Provisional.)

Employs leather or skin first soaked in sulphuric acid, and afterwards permeated with a mixture of peroxide and sulphate obtained by the treatment of minium by sulphuric acid; this is then enclosed in frames of lead or platinum.

1882. R. H. WOODLEY and H. F. JOEL. 5183.

Improvements in Secondary Voltaic Batteries and in Apparatus for Regulating their Charge and Discharge.

Lead plates are cut so as to present projecting fingers or tongue-pieces, placing on each side of the sheet a layer of prepared lead wool.

1882. H. WOODWARD. 5422.

Improvements in the Manufacture of Electrodes for Secondary Batteries.

A compound of red lead, mixed with a saccharine solution to bind the composition together, is spread over surfaces of lead.

1882. A. TRIBE. 5601.

Improvements in Secondar Batteries.

Employs a rectangular frame, with one side fitted with a lead plate, the other three sides being fitted with prepared wood, &c., to resist acid; into this chamber a mixture of peroxide of lead in admixture with compounds of lead is placed.

1882. J. LEA. 5644.

Improvements in Secondary Batteries or Electric Accumulators.—(Provisional.)

Employs copper plate coated with lead in order to increase the conductivity of the electrode.

1882. W. A. BARLOW. 5767.

(From L. Encausse and Mons. Canésie.)

Improvements in Accumulators or Secondary Batteries.

Describes method of making secondary batteries in which thin sheet lead is rolled round so as to have great length of spiral, the centre of the roll being arranged with a strip of lead; the roll is then wound with insulated wire.

One of the surfaces of the spirals is coated with an insulated varnish, and the surfaces of the spirals are not in contact with each other.

1883. T. ROWAN. 14.

Improvements in Secondary or Storage Batteries.—(Provisional.)

Consists in covering the surfaces of wood plates with grains of lead mixed with peroxide of lead.

1883. H. H. LAKE. 287.
(From N. DE KABATH.)

Improvements in Accumulators for Storing Electrical Energy, and in Devices for Facilitating the Transport thereof.—(Provisional.)

Employs a continuous length of sheet lead cut so as to present a number of lips on one side; the lead thus manufactured is then folded to form electrodes, and may then be treated by any suitable process.

1883. W. R. LAKE. 1135.
(From N. S. KEITH.)

Improvements in Electrical Accumulators or Secondary Batteries.

Describes the active part of positive electrode being deposited by electro-deposition, and the spongy metallic compound of negative electrode being deposited by electro-deposition, and either one or both electrodes being contained in a porous envelope or receptacle.

1883. T. ROWAN. 1190.

Improvements in Secondary or Storage Batteries.

Improvements to Patent 791, 1883.

Employs a box arranged with suitable grooves, into which thin sheets of lead or carbon are placed, with the intervening space filled with lead, carbon, or suitable metallic compound, and which forms compound plates. The compound carbon plate forms the positive plate, and the compound lead plate the negative plate.

1883. E. G. BREWER. 1197.
(From E. PFEIFER.)

Improvements in Secondary Piles, or Batteries, or Accumulators of Electricity.
(Provisional.)

Relates to the employment of spongy lead obtained electrolytically or by chemical precipitation.

1883. H. E. NEWTON. 1556.
(From D. MONNIER.)

Improvements in Electrical Accumulators.—(Provisional.)

Relates to obtaining porosity of the electrode by amalgamating two metals, one of which is afterwards eliminated.

1883. E. G. BREWER. 1785.

(From G. ARNOULD and R. TAMINE.)

Improvements in Secondary Piles or Batteries.

Describes electrodes made of a number of parallel wires, ribbons, or bands, built up in a frame. If two electrodes of lead are used, acidulated water is placed in the cell; but if one electrode of lead and another of copper, a solution of sulphate of copper is used.

1883. R. TATHAM and A. HOLLINGS. 1794.

Improvements in Secondary Batteries.

Describes frames for containing the active material constructed of channelled strips or bars of lead, also channelled corrugated lead, and perforated bars.

1883. P. HIGGS. 2118.

(From C. FORBES.)

Improvements in Electrical Accumulators or Secondary Batteries.

Describes electrical accumulators formed of finely-divided lead mixed with finely-pulverised graphitoidal carbon, and containing more carbon than lead. The compound is exposed to the atmosphere a sufficient length of time to cause the lead to become oxidised. The compound is then mixed with a solution of sugar in water, and then made up into plates; it is then placed between two perforated sheets of lead; it is then used as an anode in a solution of caustic alkali to clean the surface, and afterwards used as a cathode in a bath of a mercury salt in order to amalgamate the lead particles. An alloy of zinc or a plate of iron is used for the other electrode.

1883. A. PARTZ. 2358.

Improvements in Secondary Voltaic Batteries.—(Provisional.)

Describes electrodes of a lead plate completely enclosed in a casing of porous carbon, into the pores of which oxidised or finely-divided lead is placed.

1883. W. HOCHHAUSEN. 2442.

Improvements in Plates for Secondary Batteries.

Describes electrodes formed of lead plates having transverse channels; also in mixing lead with litharge while in a molten state to form plates.

1883. F. J. CHEESBROUGH. 2965.

(From C. T. TOMKINS.)

Improvements in the Method of and Apparatus for Storing and Retaining Electric Energy.

Relates to use of a negative electrode composed of a hydrogen absorbent (charcoal) combined with an electric conductor (graphite or metal) distributed throughout the mass of the absorbent.

The positive electrode is composed of a lead brush.

1883. F. M. LYTE. **3452.**

Improvements in Secondary Batteries or Accumulators.

Relates to the construction of electrodes by melting or casting the supporting material around studs, prisms, or bars of spongy lead, having studs or projections so as to be retained in place by the supporting material.

1883. A. C. HENDERSON. **3970.**

(From G. Philippart.)

Improvements in the Construction of Lead Plates for the Storage of Electro-Chemical Force in Accumulators.—(Provisional.)

Uses refined soft lead made in thin plates, which are by lamination built up into blocks, and form electrodes.

1883. A. C. HENDERSON. **4531.**

(From G. Philippart.)

Improvements in the Construction of Electric Accumulators and Secondary Batteries.

Relates to the construction of conically-shaped supports for the active matter with grooves or projections; also to the supports of a silicate conductor to prevent their peroxidation.

1883. H. F. JOEL. **4657.**

Improvements in the Construction and Regulation of Secondary Voltaic Batteries. (Provisional.)

Describes electrodes constructed of a number of lead wires, placed side by side, on which a layer of peroxide of lead is placed; on this another layer of lead wires are placed crosswise to the first layer. The plates thus constructed are tightly squeezed so as to make them more or less to cohere.

1883. H. J. HADDAN. **4801.**

(From C. F. Brush.)

Improvements in the Process or Method of, and in Apparatus for, "Forming" or Preparing Plates or Elements for use in Secondary Batteries.

In the operation of "forming" plates, a process of treatment is described which consists in successively charging, heating, and cooling the plates.

1883. I. L. PULVERMACHER. **5165.**

Improved Construction or Arrangement of Secondary Batteries or Accumulators. (Provisional.)

A core of thin metal composed of three distinct wires of different kinds, viz., a thin platinum wire, a copper wire, and a lead wire. A lead wire is wound on this core with its coils a slight distance apart to form interstices for the reception of a paste of oxide of lead

1883. F. M. LYTE. **5469.**

Improvements in Secondary Batteries or Accumulators.

Improvements to Patent 3452, 1883.

States that the supports referred to in the previous patent may be made of lead or pewter, antimonial lead, or type, or Britannia metal, placed back to back, with or without a central plate of some conducting material placed between them, against which the prisms rest and are pressed closely in contact.

1883. G. F. PRESCOTT. **5524.**

Improvements in Secondary Batteries.—(Provisional.)

Electrodes formed by taking lead and oxide of lead and mixing them while at a high temperature; the composition is then solidified by pressure.

1883. A. C. HENDERSON. **5759.**

(From N. Bassett.)

Improvements in Secondary Electric Batteries.

Relates to the preparation of peroxide of iron as a coating to the electrodes, and with the solution of proto-chloride of iron.

1883. H. WOODWARD. **5843.**

Improvements in Secondary or Storage Batteries.—(Provisional.)

Uses lead tubes filled with litharge, peroxide, or other salt of lead, a number of holes being pierced in the tubes.

1884. E. P. ALEXANDER. **1709.**

(From J. L. Moisy.)

Improvements in Accumulators or Secondary Batteries.—(Provisional.)

Relates to the construction of a battery with the elements composed of comb-like bands or strips of lead folded or doubled transversely, and having their opposite ends united together.

1884. H. J. HADDAN. **3579.**

(From C. F. Brush.)

Improvements in the Process or Method of Casting Plates for use as Elements in Secondary Batteries, and in Apparatus to be used therefor or in connection therewith.

Relates to a method of casting lead plates by dipping a hinged mould into molten lead. Also describes apparatus used for same.

1884. S. KALISCHER. **4782.**

An Improvement in Secondary Batteries.

Uses an anode of steel or iron having a coating of peroxide of lead.

1884. S. KALISCHER. 5337.

An Improvement in Secondary Batteries.

Uses an anode of carbon having a coating of peroxide of lead.

1884. E. JONES. 6068.

Improvements in Secondary Batteries.—(Provisional.)

Describes electrodes constructed of metallic strips arranged in comb-like fashion in a supporting frame, a clear space being left between the strips for the reception of another electrode similarly constructed.

1884. J. S. SELLON. 6228.

Improvements in Secondary Batteries or Electrical Accumulators.—(Provisional.)

Relates to the construction of plates of a conical or pyramidal shape.

1884. H. F. JOEL. 6646.

Improvements in the Construction of Secondary Voltaic Batteries.—(Provisional.)

Electrodes constructed with an alloy of lead and tin, and made in the form of a grid, or built up of open wire or gauze, or a plate with chequer-shaped openings. Lead wool is used as described in Woodley and Joel's patent (No. 5183, 1882).

1884. J. S. BEEMAN. 9113.

New or Improved Constructions of Electrodes for Primary and Secondary Batteries. (Provisional.)

Describes method of constructing comb-like teeth of electrodes so that they are capable of bearing their own weight among themselves.

1884. H. J. HADDAN. 9195.
(From L. Epstein.)

Improvements in the Production of Plates or Electrodes for Secondary Batteries. (Provisional.)

Relates to the production of a finely-divided lead compound by adding an oxide or salt of lead to molten metallic lead, and stirring the mixture until the liquid mass has been transformed into a finely-divided solid body.

1884. A. TRIBE and A. P. PRICE. 9488.

Improvements in Secondary Batteries.—(Provisional.)

Relates to the making of the foundation plates for the positive element of lead either entirely or partly converted into lead sulphide, lead phosphide, or lead arsenide.

1884. A. TRIBE. 9489.

Improvements in the Construction of Secondary Batteries.—(Provisional.)

Relates to the employment with the negative element of "leads" of lead entirely or partially converted into lead sulphide, lead phosphide, or lead arsenide.

1884. W. TAYLOR and F. KING. 9735.

Improvements in Secondary Batteries.—(Provisional.)

Relates to the construction of electrodes of flat rings or of a helix or helices of lead so placed as to form a cylinder; by this arrangement the liability to buckle being obviated.

1884. R. TAMINE. 12824.

Improvements in Electrodes for Secondary Batteries.

Relates to construction of electrodes composed of the following ingredients:—Resin, oxide or peroxide of lead, and lead filings, in certain proportions.

1884. G. G. ANDRÉ. 13752.

Improvements in Secondary Batteries, partly applicable also to Primary Batteries.

Relates to the constructing of elements of lead lapped or wound spirally round a wooden core, and then with canvas or calico tape or other suitable porous non-conducting material.

1884. J. S. WILLIAMS. 13879.

Improvements in the Construction and Working of Electric Accumulators, and in Apparatus or Means therefor.

Relates to the construction of conducting channels secured to the edges of the electrodes so as to provide for rapid charging or discharging without heating.

1884. J. MŸERS. 14200.

An Improved Accumulator of Electricity.

The positive plates are made of carbon, with holes perforated in same, and covered on both sides with a layer of finely-divided lead, prepared by reducing sulphate of lead by zinc in a solution of natrium; the plate thus prepared is covered with parchment and enveloped in linen. Negative plates made of carbon or copper, and covered with lead or zinc. A solution of sulphate of zinc is used in the cells.

1884. R. H. RADFORD. 14981.

(From H. F. B. Schaefer.)

Improvements in the Construction and Application of Carbon or Carbonaceous Electrodes, called "Hose Electrodes," for Primary and Secondary Elements.

Relates to the construction and application of hose tissues from metallic threads or wires as a covering for the electrodes.

1885. W. R. LAKE. 2765.

(From A. Marchenay.)

Improvements in and relating to Electrical Accumulators or Secondary Batteries.

Describes the use of plates of crystallised chloride of lead.

SUBDIVISION V.

SUBDIVISION OF THE CURRENT.

1882. J. S. WILLIAMS. 1174.

Improvements in and relating to the Generation, Distribution, Storing, Utilisation, Measuring, and Regulation of Electricity, and Apparatus or Means therefor.

Utilises water supply to towns, &c., to drive water-wheel or turbine combined with dynamo to generate electric currents. These electric currents are led to storage batteries which are provided with conductors or mains to the cities or towns or places where light or motive power is required.

Where there is a large supply or head of water a series of pipes with turbines and dynamos can be used.

Employs storage battery for exciting the field magnets of the dynamo.

Proposes to utilise the power generated in the manner described for driving tramcars.

Proposes use of incandescent lamp in mines.

In primary battery employs iron or steel filings oxidised.

Dynamo with armatures revolving at each end of field electro-magnets; the armatures are wound with wire or ribbon; commutators revolve in a liquid to carry off the current.

1882. S. PITT. 3330.

(From E. T. Starr and W. J. Peyton.)

Improvements in Electric Lighting and Power Distributing Systems.

Describes a complete system of lighting with dynamos, secondary batteries, and lamps, &c.

882. T. J. HANDFORD. 3355.

(From T. A. Edison.)

Improvements in Means or Apparatus employed in or for Supplying Electricity for Light, Power, and other purposes.

Describes a system of generators, connections, and other devices.

1882. J. HOPKINSON. 3576.

Improvements in Distributing and Measuring Electricity, and in Apparatus to be employed for those purposes.

Relates principally to maintaining the electro-motive force on a system of conductors at a fixed potential.

Describes also improvements in electric current meter.

1882. T. J. HANDFORD. **3752.**
(From T. A. EDISON.)

Improvement in Means employed in or for Transmitting Electricity for Light, Power, and other purposes.

The object of this invention is to produce efficient means for dividing an electric current of high electro-motive force or tension into a number of currents of lower electro-motive force, and for making all the lamps, motors, &c., operated by the current of low tension independent of each other.

1882. T. J. HANDFORD. **3949.**
(From T. A. EDISON.)

Improvements in Means or Apparatus employed in or for Supplying Electricity for Light, Power, and other purposes.

Provides for reducing the tension of a continuous current for use in a consumption circuit having translating devices arranged in multiple arc below that of the main circuit by means of induction apparatus placed between the circuits, and consisting of intermediate double-wound magnetic coils.

1882. T. J. HANDFORD. **3996.**
(From T. A. EDISON.)

Improvements relating to Dynamo- and Magneto-Electric Machines, for Regulating the Generation of Current by such Machines.

Employs, in combination with a dynamo, a translating device consisting of an adjustable resistance operated by an electro-magnet, located in mutiple-arc circuits from main conductors.

1882. L. GAULARD and J. D. GIBBS. **4362.**

A New System of Distributing Electricity for the Production of Light and Power.

Employs an alternating current of high tension for the generation of an unlimited number of secondary generators of induced currents.

1882. A. R. SENNETT. **4492.**

See Dynamo- and Magneto-Electric Machines of the Gramme type.

1882. J. D. F. ANDREWS. **4511.**

Improvements in Apparatus for Storing, Measuring, and Regulating Electricity.

Describes a combination of two accumulators with apparatus for effecting alteration of their charge from a main circuit, and their discharge to a third accumulator, so as to maintain continuous supply of electricity to a local circuit.

1882. T. J. HANDFORD. **4884.**
(From T. A. EDISON.)

Improvements in and relating to Systems of Electrical Distribution, and Apparatus or Means for Regulating the Current in such Systems.

Describes, in a system of distribution, the combination with the intersecting

positive and negative main conductors of feeding conductors running to centres of consumption, where they are connected to the main conductors. Auxiliary circuits connected at their terminals with the feeding conductors of a device for indicating the electric pressure.

1882. T. J. HANDFORD. 6199.
(From T. A. Edison.)

Improvements relating to the Distribution of Electrical Energy for Light, Power, and other purposes.

Describes the use of separate adjustable resistances in the main conductors in a compensating system having dynamo machines, secondary batteries, or other sources of energy in series, and one or more conductors running back to the divided source.

1883. F. J. CHEESBROUGH. 3.
(From E. R. Knowles.)

An Improved System or Combination of Electrical Apparatus and Conductors to be used in the Application of Electricity to Practical Use, and especially to Domestic or House Lighting.

A system of storing and applying electricity is described. Dynamos, lamps, switches, system of connecting wires, and circuits are described.

1883. S. PITT. 17.
(From E. T. Starr and W. J. Peyton.)

Improvements in Electric Lighting and Power Distributing Systems.

Relates to a system of distribution from generators by means of automatic or time switches, whereby an electric current may be automatically directed to or cut off from apparatus at predetermined times.

1883. J. S. WILLIAMS. 24.

Improvements in and relating to the Generation, Storage, Distribution, Regulation, Measurement, and Utilisation of Electricity, and Apparatus or Means therefor, &c.

Relates to improvements in machines, details of apparatus and systems of connections, &c.

1883. J. S. SELLON. 217.

mprovements in Working and Regulating Secondary Batteries, and in Machinery or Apparatus therefor or connected therewith.

Relates to an automatic switching apparatus for cutting out cells from the charging circuit, to prevent overcharge of cells; also to the application to dynamo-electric machines of a switch to readily change the connections, to give different strengths of current.

1883. A. MUIRHEAD. 275.

Improvements in the Method of and Arrangements for Applying Alternating Currents to the Production of Light.—(Provisional.)

Places a condenser either in the main circuit or derived circuit.

1883. J. S. WILLIAMS. **2147.**

Improvements in and relating to the Generation, Storage, Regulation, Distribution, and Utilisation of Electricity, and Apparatus or Means therefor, and in Methods or Means to be employed in the Construction of such Apparatus or Parts thereof.

Relates to apparatus for generation, and methods of storage and distribution, and application to railways.

1883. J. S. WILLIAMS. **2148.**

Improvements in and relating to the Generation, Storage, Regulation, Distribution, Measurement, and Utilisation of Electricity, and Apparatus or Means therefor, and in Methods or Means to be employed in the Construction or Operation of such Apparatus or Parts thereof.

Relates to methods for utilising surplus power in manufacturing establishments for storing and distributing electric currents.

1883. T. J. HANDFORD. **2857.**

(From T. A. EDISON.)

Improvements relating to Systems of Generation and Distribution of Electricity for Light, Heat, and Power.

Relates to applying to systems of distribution a mode of maintaining the balance of the system by shifting circuits containing translating devices from one part of the system to another. Also relates to the combination with a divided source of energy supplying translating devices arranged in multiple series, and means for regulating the electro-motive force of each division of such source of energy independently of the other divisions.

1883. H. E. NEWTON. **3219.**

(From A. I. GRAVIER.)

Improvements in the Distribution of Electric Currents.—(Provisional.)

Relates to charging a network of distribution with currents emitted under high pressure and transformed into useful currents of low pressure.

1883. ST. G. LANE FOX. **3692.**

An Improved System of Electrical Distribution.

Relates to a means of transmitting energy from a distant source by means of high-tension currents, and distributing it over districts where it is to be utilised by means of low-tension currents.

1883. J. S. WILLIAMS. **5109.**

Improvements in and relating to the Generation, Storage, Regulation, Distribution, and Utilisation of Electricity, and Apparatus or Means therefor, and in Methods or Means to be employed in the Construction of such Apparatus or Parts thereof.

Relates to a system of storage and distribution, and construction of apparatus, more specially adapted for construction of electric railways.

1883. J. S. WILLIAMS. **5110.**

Improvements in and relating to the Distribution, &c., of Electricity, &c.

Relates to a method for utilising any surplus of electric power, and operating the producing plant advantageously on an electrical system.

1884. L. GAULARD and J. D. GIBBS. **2858.**

Improvements in Means for Producing and Utilising Currents in Secondary Circuits.

Relates to a system of distribution by induction coils placed in series, and refers to methods of arranging the circuits and of the wires on the coils.

1884. S. PITT. **16910.**

(From T. B. E. Turretini.)

Improvements in the Distribution of Electricity.

Relates to the distribution of electricity by the establishment of a central generating station, feeding accumulators at one or more secondary stations by currents of high tension passing and returning directly from the central station to a secondary station, these currents of high tension being changed into currents of low tension by groups of accumulators at each secondary station.

1884. W. H. SCOTT and E. A. PARIS. **6260.**

See Dynamo- and Magneto-Electric Machines—Miscellaneous.

1885. W. P. THOMPSON. **3379.**

(From C. Zipernowsky and Max. Déri.)

Improvements in Distributing Electricity and in Apparatus therefor.

Describes the employment of a constant exciting current, with a variable current which by the aid of a special induction coil is made directly dependent upon the conditions of the current in the external circuit, and the combination of these two currents in one, two, or more, separate windings of the magnets.

SUBDIVISION VI.

MISCELLANEOUS.

I.—REGULATION OF THE CURRENT BY RESISTANCE OR OTHERWISE.

1882. T. J. HANDFORD. **1191.**
(From T. A. EDISON.)

Improvements relating to Dynamo- or Magneto-Electric Machines, for Regulating the Generative Capacity of such Machines.

Describes regulator with electro-magnet and armature lever, which are placed in circuit with lamps, and the armature of the regulator being adjusted to operate resistances by putting them in or out of circuit of the field electro-magnets of dynamo when lamps are turned on and off.

A series of the above regulators are also used in multiple arc.

1882. P. M. JUSTICE. **1895.**
(From A. CRUTO.)

See Electrodes for Incandescent Lamps.

1882. W. ARTHUR. **2128.**

Improvements in Regulating and Utilising Electric Currents.

Subdivision of electric current is effected by breaking up a main cable a two stations, say at different ends of a street, into a number of smaller cables or wires, equal to the number of lamps required between the stations, and each wire being connected and balanced so that the resistance may be equal.

Describes also the use of an accumulator at the lamp, so that when the lam is turned on the accumulator is cut out of circuit, and *vice versa.*

1882. J. C. MEWBURN. **3054.**
(From F. RIGAUD.)

Improvements in the Means or Apparatus for Regulating the Production of Electricity.
(Provisional.)

This invention consists in principle in modifying the speed of the electric generator so as to keep constant the difference of potential, and this without changing the speed of the engine.

1882. F. C. PHILLIPS. 4691.

Improvements in the Generation and Distribution of Electric Energy, and in Apparatus therefor.

Relates to apparatus for putting electric machines arranged in parallel arc, out of circuit when the requirements or conditions of that circuit fall below a determined amount, and for putting the same into circuit when the requirements of the circuit rise above a determined amount.

1882. R. E. B. CROMPTON and G. KAPP. 4810.

Improvements in Dynamo-Electric Machines.

Relates to the use of two circuits on the field magnets, connected respectively in shunt and in series with the external circuit, for the purpose of keeping the electro-motive force of the machine constant at a constant speed when the resistance of the external circuit varies.

1882. L. CAMPBELL. 5014.

Improved Means of Regulating Electric Currents and Electro-motive Force, and Apparatus therefor.

Describes dynamo machines wound with their field-magnet coils in several sections, instead of being in one conductor, the several ends of the coils being brought to a commutator or switch; an automatic motor is connected to the brushes of the armature commutator and to the switch above referred to.

1882. H. WILDE. 5677.

Improvements in Mechanism for Regulating the Production of Electricity.
(Provisional.)

Describes mechanism by which the speed of the electro generating machine is regulated to supply the varying amount of electricity to maintain the varying number of lamps in the circuit to their normal degree of incandescence.

1882. J. T. KING. 5744.
(From J. R. FINNEY.)

Improvements in Apparatus or Appliances for Automatically Regulating Electric Currents.

Relates to the automatic adjustment of the collecting brushes of a dynamo-electric machine, or to a resistance. Various devices for effecting the above are described.

1883. J. S. SELLON. 217.

See Subdivision of the Current.

1883. A. GRAY. 634.
(From T. GRAY.)

See Lamps—Arc—Vertical Carbons.

1883. W. J. L. HAMILTON. **2850.**

See Electrodes for Incandescent Lamps.

II.—LIGHTING RAILWAY CARRIAGES BY ELECTRICITY.

1882. T. J. HANDFORD. **2336.**

(From W. A. STERN and H. M. BYLLESBY.)

Improvements in or relating to Dynamo- or Magneto-Electric Machines and Apparatus for Lighting Railway Carriages, &c., by Electricity.

Describes combination of generator, storage batteries, and switches for operating same; armatures revolved by connection with wheels of carriages.

Method of connections, &c., are also described.

1882. M. A. WIER. **2557.**

Improvements in the Illumination of Railway Carriages by Electric or other Lights.

(Provisional.)

Powerful electric or other lamps are placed at the extremities of the train. The distribution of the rays of light is effected by means of reflectors and prismatic refractors fixed on the sides and roof of each compartment.

1882. H. E. NEWTON. **4087.**

(From SOCIÉTÉ UNIVERSELLE D'ELECTRICITÉ TOMMASI.)

Improvements in the Lighting of Railway Trains by Electricity, and in Apparatus to be used therefor.

Improvements to Patent No. 4057, 1881.

Relates to improved automatic contact-breakers, arrangement of magneto-electric machines, also of a rocking contact-breaker, admitting of the light being more uniform, and during the journey putting the electric generators and accumulators at the same time in connection with the lamps, and during stoppages putting the accumulators alone in connection with the lamps, the generator being cut out of the circuit.

1882. P. R. ALLEN. **5899.**

Improvements in Apparatus for Lighting, Heating, and Communicating by Electricity; applicable in part to other purposes.

Improvements to Patent 2215, 1881.

Describes the application of electric lighting to carriages and engine, and system for carrying same into effect.

1883. **A. M. CLARK.** **631.**

(From N. de Kabath.)

Improvements in and connected with Electric Lighting Apparatus for Railway and other Carriages.—(Provisional.)

Relates to a self-contained lamp and storage cell, and also to station apparatus for recharging the lamp when exhausted.

1883. **J. S. WILLIAMS.** **2147.**

See Subdivision of the Current.

1883. **J. S. WILLIAMS.** **5109.**

See Subdivision of the Current.

1883. **W. STROUDLEY and J. HOUGHTON.** **2579.**

Improvements in the Means and Apparatus for Electric Lighting on Railway Trains and other Vehicles; also partly applicable for the Production of Electric Currents generally.

Describes the employment of a governor, driven from the armature shaft, which brings one or other distinct set of brushes in contact with the commutator, to supply currents always in the proper direction.

Also describes exciting the field magnets of dynamo with secondary batteries.

1884. **W. A. DUNCAN.** **15574.**

Electric Lighting of Trains and other Vehicles.

Relates to the fixing of the armature of dynamo on the axle of locomotive or railway carriage or other vehicle, the field electro-magnets being also carried by the same axle.

1885. **A. M. CLARK.** **1785.**

(From The Maschinenfabric, Esslingen, and The Electrotechnische Fabric, Cannstatt.)

Improvements in Apparatus for Lighting Railway Carriages by Electricity.

Relates to the lighting of railway trains or single carriages, whether travelling or stationary, by incandescent lamps with dynamos and accumu lators, the motive power being derived from wheel axle.

1885. **J. E. H. GORDON.** **5657.**

Improved Means or Apparatus for Lighting Railway and other Signal Lanterns by Electricity.

Relates to the use of incandescent electric lamps in railway signal lanterns, in combination with switching apparatus.

III.—VARIOUS.

1882. J. S. WILLIAMS. **1556.**

Improvements in and relating to the Generation, Storage, Distribution, Regulation, and Utilisation of Electricity, and Apparatus or Means therefor.

System for using storage batteries, and methods of distribution, and improvements on Patent 1174, 1882.

1882. W. B. BRAIN. **1616.**

Improvements in the Mode of and Machinery for the Production of Electric Currents. (Provisional.)

Proposes to do away with the use of commutators, and in doing so proposes to use an iron core of shape similar to Siemens' H armature. Field magnets may be of any of well-known forms.

1882. J. MUNRO. **1626.**

Improvements in Electric Light and Power Apparatus.

Employs a rotary or vibratory device which serves the current to a number of circuits.

Arc lamp with an iron core, cone-shaped, and surrounding the carbon rod; the core, when drawn in by a solenoid by the current, clamps the rod holding the carbon.

Surrounds carbon points with a refractory material.

1882. J. B. ROGERS. **1999.**

Improved Means of Accumulating and Storing Electric Currents, and of Economically Utilising the Energy so Stored for Lighting purposes.

Describes small secondary batteries used in conjunction with larger secondary batteries, and states that the currents in the small batteries are stored as intensity currents, and in the large as quantity currents.

1882. J. C. ASTEN. **2020.**

Improvements in Apparatus or Means for Obtaining Electric Light.—(Provisional.)

Makes the outer or positive carbon or pole of a hollow form, in the interior of which the negative carbon or pole is inserted.

1882. A. MILLAR. **2138.**

Improvements in Apparatus for Producing Electric Currents, also applicable for Electro-motive Power purposes.—(Provisional.)

A large number of horse-shoe magnets are fastened together to form a continuous circle or ring, the poles being all in the same plane; also fastens them so that the poles point outwards and form the periphery of the disc.

Coils of wire are placed in the channel between the poles, and the disc with the magnets revolved.

1882. H. LEA. 2186.

Improvements in Incandescent Electrical Lamps.

Employs T-shaped head made on the glass globes, and also socket for same to fit into.

1882. H. WILDE. 2256.

Improvements in Apparatus for Regulating and Directing Electric Light.
(Provisional.)

Improvements to Patent 618, 1873.

Places one or more electro-magnetic coils in close proximity to the arc, to prevent the arc from travelling round the carbons.

1882. J. LANE. 2752.

Improvements in the Construction of Electric Lamps, and in Apparatus employed therein.

Describes several methods of fixing the plug which holds the filaments into the glass globes.

1882. C. WESTPHAL. 2823.

Improvements in the Method of Generating and Storing Electric Energy, and in Apparatus therefor or connected therewith.

Describes method of producing from coals a constant current of electricity by means of water, gas, and oxygen, or atmospheric air, which gases are applied for artificially producing on plates or electrodes the same condition or state assumed by the latter during the electric decomposition of water.

1882. S. H. EMMENS. 2912.

Improvements in Apparatus for the Regulation of Electric Currents.

Describes an automatic reversing apparatus or switch used with secondary batteries in conjunction with dynamos, and interposed with the same and the service circuit for the maintenance of the latter.

Also describes an apparatus for charging batteries in parallel and discharge in series.

1882. O. G. PRITCHARD. 2974.

Improvements in the Means of Producing the Electric Light.—(Provisional.)

Uses gas flame in combination with an electric arc, and finely-divided carbon supplied to the arc in a constant stream.

1882. F. MORI. 3821.

Improvements in Electric Lamps.

Describes an automatic switch for commutating the current from one pair of carbons to another pair in lamps constructed to use parallel carbons.

1882. W. R. LAKE. 4270.
(From E. Brard.)

Improvements in and relating to Apparatus for Generating Electricity, and applicable for Lighting or Heating purposes.

Describes the construction of electric bricks or blocks, or candles, composed of agglomerated coal dust or the like, and a layer of nitrate, these two elements containing wires whose ends project from the bricks. When the bricks are made to burn at the opposite extremity to their poles a very energetic current is established.

1883. E. C. G. THOMAS. 2448.

Improvements in Electric Light Buoys.

Describes water-wheels which are mounted in channels or hollows at the side of the buoy. A dynamo and an accumulator, and also a clockwork arrangement to make contact at predetermined times, are provided.

1884. S. H. EMMENS and R. BARLOW. 409.

Improvements in Electric Lamps.—(Provisional.)

Relates to the combination of a galvanic element in an air-tight case with a lamp and circuit-closing apparatus so arranged as to be capable of use in explosive atmospheres.

1884. L. GAULARD and J. D. GIBBS. 2858.

See Subdivision of the Current.

1884. A. M. CLARK. 7439.
(From G. Trouvé.)

Improved Portable Apparatus for Electric Lighting purposes.

Describes an apparatus consisting of an incandescent lamp and battery, and the means of raising the electrodes out of the solution when not in use.

1884. E. T. BOSTON. 8921.

A Portable Safety Electric Lamp for Miners, Divers, and other purposes.
(Provisional.)

A primary battery forms the base of the lamp, on the top of which is placed an incandescent lamp protected by an outer thick glass and metal guard.

1884. J. S. WILLIAMS. **1388.**

Improvements in Self-contained or Portable Electric Apparatus for Electric Lighting or otherwise Utilising Currents of Electricity.

Employs an incandescent lamp in combination with an accumulator and a variable resistance, constructed in a portable form for table or other use.

1884. R. ROSE. **16361**

Improvements in Obtaining Electric Currents for Lighting and other purposes.

Describes a system or mode of obtaining a current of electricity by means of a current of air actuating wind vanes or fans arranged so as to drive a dynamo-electric machine.

1885. A. V. ROSE and G. F. ROSE. **3987.**

An Improved Portable Electric Lamp.

Describes an incandescent lamp mounted on a pedestal on the top of a box containing the battery. An arrangement is provided for lowering the elements of the battery in the liquid.

1885. F. J. MICKLEWRIGHT. **4723.**

Improvement in Aërial Electric Signalling Apparatus

Describes a frame with three incandescent lamps placed one above the other for code signalling purposes.

JOURNAL

OF THE

SOCIETY OF

Telegraph-Engineers and Electricians.

Founded 1871. *Incorporated* 1883.

Vol. XV.	1886.	No. 64.

The One Hundred and Fifty-eighth Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, November 11th, 1886—Professor D. E. Hughes, F.R.S., President, in the Chair.

The minutes of the previous meeting were read and approved.

The names of new candidates for admission into the Society were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Brackenbury Bayly.

The Right Hon. J. H. A. Macdonald, C.B., Q.C., M.P. (Lord Advocate).

D. J. McGauran.

From the class of Students to that of Associates—

George K. B. Elphinstone.

Donations to the Library of the Society were announced as having been received since the last meeting from the Astronomer-

Royal; the Institution of Civil Engineers; the Royal Commission for Victoria to the Colonial and Indian Exhibition; the Franklin Institute; the School of Submarine Telegraphy; Professor E. J. Houston; Professor J. E. Ewing; C. M. Gariel, Esq.; H. R. Rogers, Esq.; G. T. Carruthers, Esq.; Professor Hughes, President; Col. Sir J. U. Bateman-Champain, R.E., P.P.; Dr. J. Hopkinson, V.P.; G. de la Touanne, Foreign Member; W. Ellis and Killingworth Hedges, Members; N. K. Cherrill, Gisbert Kapp, Julius Maier, C. H. B. Patey, and A. A. C. Swinton, Associates; to all of whom the thanks of the meeting were unanimously accorded.

The following paper was then read:—

THE PRE-DETERMINATION OF THE CHARACTERISTICS OF DYNAMOS.

By GISBERT KAPP, Associate.

If we know the number of magnetic lines of force which pass through the cross section of the armature core at the neutral points, the internal electro-motive force developed can easily be calculated from the winding and the speed. Adopting, for convenience of calculation, as a unit line that which is equivalent to 6,000 lines in the C.G.S. system of measurement, we have

$$E_a = z_1 \, N t \, n \, 10^{-6},$$

where E_a is the E.M.F. developed, z_1 the number of unit lines passing through both neutral sections, $N t$ the number of conductors counted all round the armature, and n the speed in revolutions per minute. This formula applies equally to cylinder, disc, and drum armatures, but in the former two types $N t$ represents the number of complete convolutions on the armature, whilst in the latter it represents twice that number. The formula also applies equally to bipolar and multipolar machines, the only difference being that in the latter cases the neutral sections to be considered are not diametrically opposite.

The question to find the E.M.F. of a given armature therefore resolves itself into the determination of z_1, the number of lines passing through the armature core; and in the following I would submit a suggestion for the solution of this problem, if the con-

structive details of the machine, the exciting power, and the quality of iron are known. Stated in other words, the problem is to construct the characteristic curve of a dynamo from its drawing without having recourse to experiment.

Since the usual characteristic representing the relation between exciting current and electro-motive force depends on the speed, it is more convenient to use the characteristic of magnetisation, where abscissæ represent exciting power and ordinates the number of useful lines. As far as I am aware, the only attempt to represent the relation between these quantities mathematically is the ingenious and very simple formula by Fröhlich, which has been further developed by Professor Silvanus Thompson. According to the original notation of Fröhlich the effective magnetism (M) is represented by

$$M = \frac{i}{a + b\,i},$$

where i is the current of a series-wound dynamo (therefore proportional to the exciting power), and a and b are constants to be determined experimentally for each machine. For an infinite current the magnets become saturated, and the effective magnetism equals $\frac{1}{b}$. If now absolute saturation be considered as unity, and actual magnetisation be expressed in reference to it, the formula is further simplified to

$$M = \frac{i}{a + i}.$$

In this case the constants to be determined experimentally are a and the E.M.F. corresponding to saturation. In Professor Thompson's well-known modification of this formula, $H = \frac{G\,\kappa\,S\,i}{1+\sigma S\,i}$; there are also two constants which require experimental determination—G, the geometrical constant depending on the configuration of the machine, and the saturation coefficient σ, "which is the reciprocal of that number of ampère turns that will bring the magnet up to such a degree of saturation that its susceptibility is halved."

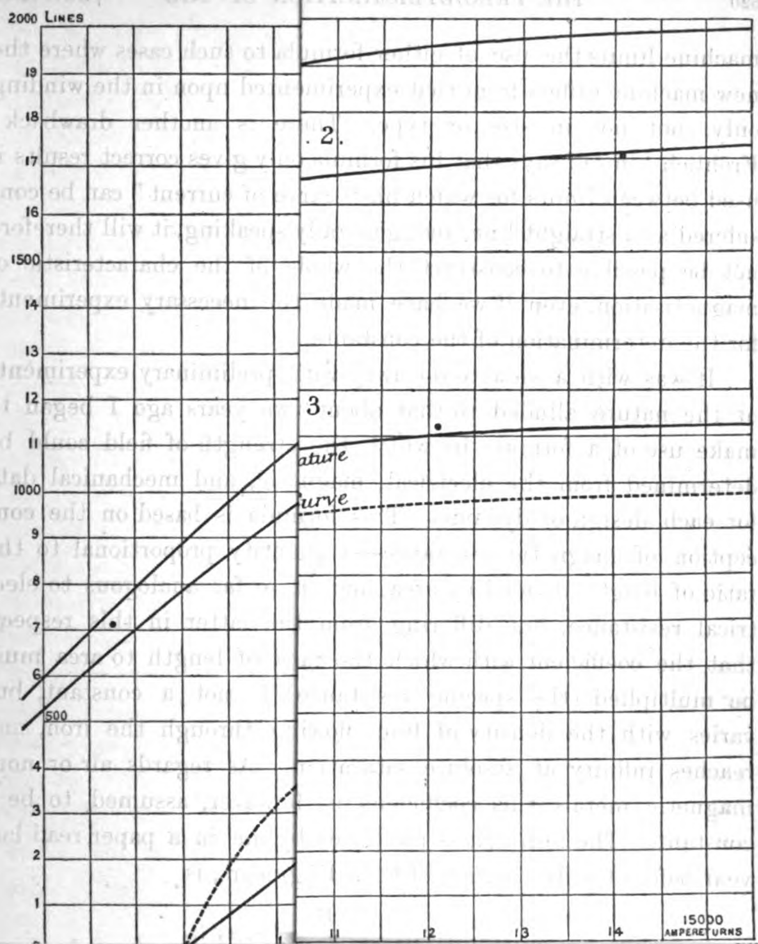
Now this necessity of making at least two experiments in order to determine the value of the constants in each particular

machine limits the use of either formula to such cases where the new machine differs from that experimented upon in the winding only, but not in size or type. There is another drawback: Fröhlich himself says that his formula only gives correct results if used between limits for which his "curve of current" can be considered as a straight line, and, generally speaking, it will therefore not be possible to construct the whole of the characteristic of magnetisation, even if we have made the necessary experiments for the determination of the constants.

It was with a view to do away with preliminary experiments of the nature alluded to that about two years ago I began to make use of a formula by which the strength of field could be determined from the electrical, magnetic, and mechanical data for each design of dynamo. This formula is based on the conception of magnetic resistance—a quantity proportional to the ratio of length divided by area, and in so far analogous to electrical resistance, but differing from the latter in this respect, that the coefficient with which the ratio of length to area must be multiplied (the specific resistance) is not a constant, but varies with the density of lines flowing through the iron, and reaches infinity at absolute saturation. As regards air or non-magnetic metals this coefficient is, however, assumed to be a constant. The formula, as published by me in a paper read last year before the Institution of Civil Engineers, is

$$z_1 = \frac{P}{R_a + R_a + R_f},$$

where P is the exciting power in ampère turns applied to the horse-shoe magnet which produces the lines z_1, and R_a, R_a, R_f, are the magnetic resistances of air space, armature, and field magnet respectively. The resistance of air space is found by multiplying twice the interpolar distance given in inches (twice, because the lines must leap into *and* out of the armature) with the constant 1440, and dividing the product by the polar area. In this case the numeric 1440 is the specific magnetic resistance of air in the arbitrary system of measurement we have adopted. The other two resistances are for very low degrees of magnetisation, found in like manner by determining from the drawing of


2000 LINES
19
18
17
16
1500
14
13
12
11
1000
9
8
7
6
500
4
3
2
1
2.
3.
ature
urve
11
12
13
14
15000
AMPERETURNS

the dynamo the average distances through which the lines flow in armature and magnet, and dividing by the respective areas; the ratio in each case being multiplied by the numeric 2, which represents the initial specific magnetic resistance of annealed wrought iron. The above empirical formula is only correct for low degrees of magnetisation, and consequently for comparatively weak exciting powers. Assume we have made the calculation and determined the ratio (represented by a straight line) between E_a and P for a given speed. If we now work the dynamo under these conditions, we find that the actual E.M.F. observed is either equal to or slightly higher than the calculated E.M.F., but seldom lower. In other words, the actual initial value of the magnetic resistance is either equal to or slightly less than the calculated value. This is probably due to the neglecting of the influence of edges of pole-pieces, and to errors in estimating the lengths and areas of the flow of lines. Nature finds the easiest way for this flow, and since it is obviously impossible for us in our calculation to hit on a still more easy way, we are likely to obtain (when working with the greatest possible care) a slightly higher resistance. The error is, however, generally very small, and is of no influence on that part of the curve which is of practical importance.

Before entering into the question of how this part of the curve can be obtained, it will perhaps be best to illustrate by analogy to the voltaic circuit the conception on which the

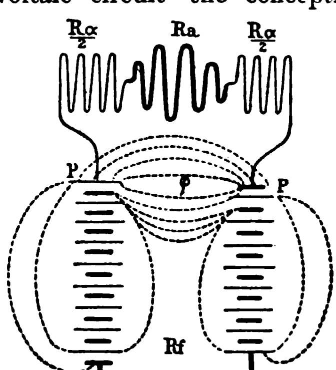


Fig. 1

formulæ to be given are based. Let, in Fig. 1, R_a represent a

certain resistance (corresponding to the magnetic resistance of the armature core), connected by resistances $\frac{R_a}{2}$ (representing the two air spaces) with the poles ($p\ p$) of a voltaic battery having a resistance R_f (corresponding to the field magnet) and an internal electro-motive force P (exciting power).

Imagine at first the apparatus well insulated, then the current z_1 is given by the ratio of P and the sum $(R_a + R_a + R_f)$.

If now the battery be submerged into a badly-conducting medium, currents will flow as shown by the dotted lines, and consequently through certain cells a current flows which is larger than the useful current in R_a. It is impossible to say exactly in what manner these currents of leakage are distributed, but it is evident that the most serious loss must occur between the poles, where the difference of potential is a maximum, and that in a given medium and arrangement of battery the total loss through leakage can be considered as approximately proportional to the difference of potential between the poles. Let the latter have the value p_1, then the current lost, ζ, equals p_1/ρ, if by ρ we represent the average resistance of the surrounding medium for this particular configuration of battery. We can also, with fair approximation, put the current in the battery—

$$z_2 = z_1 + \zeta.$$

Now imagine that by some means we can give to the electro-motive force (P) of the battery any value between zero and that value which will produce the maximum current (z_1) required. It will then be possible to determine what electro-motive force is required for each value of z_1 between zero and maximum. To do this we proceed as follows:—We determine first the difference of potential at the poles—

$$p_1 = (R_a + R_a)\, z_1 \quad \ldots \ldots \ldots \ldots \ldots \quad (1)$$

then the loss by leakage—

$$\zeta = \frac{p_1}{\rho} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2)$$

then the total current—

$$z_2 = z_1 + \zeta \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (3)$$

then the loss of electro-motive force (p_2) occasioned by the internal resistance of the battery—

$$p_2 = R_f\ z_2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

and, finally, the total E.M.F.—

$$P = p_1 + p_2 \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

The submerged battery is analogous to a horse-shoe magnet, since the latter is always surrounded by a medium which allows the passage of magnetic lines. To the electro-motive force of the battery corresponds the total exciting power applied to the magnet; to the currents z_2, z_1, and ζ correspond numbers of lines respectively created within the magnet core, passing through the armature, and lost by leakage; the analogy of resistances has already been mentioned.

Since for small degrees of magnetisation the resistances of armature and magnet are not very different from their lowest initial values, which are very small in comparison with the resistance of leakage, it follows that for the early stages of magnetisation leakage has very little influence on the exciting power; in other words, that the creation of leakage or waste field does not materially increase the expenditure of energy required to produce the useful field. For a more intense magnetisation, such as found in the usual working conditions of dynamos, the case is, however, very different. In the first place, the resistance of the armature has now considerably increased, and with it has increased at a still faster ratio p_1, that portion of the exciting power (or magnetic pressure at the field-poles, if I may be allowed to use a somewhat unscientific term) which is necessary to force the lines through air space and armature. The immediate result is a large increase of the waste field, which has to be provided for by the magnet; augmenting, therefore, the density of lines in the case of the latter considerably beyond the value which would otherwise correspond to the useful field. Hence large increase of magnetic resistance, and consequently also of exciting power. This fact—that the number of lines created must be sensibly greater than the number utilised—explains at once the necessity of making the area of the magnet core considerably larger than that of the armature core. If, with a

view to get an equal density of useful lines in armature and field, and thus save weight, the cross section of the magnet be reduced to that of the armature, it will be found absolutely impossible to saturate the latter, no matter how much exciting power we put on. A machine so constructed would therefore be a failure, not only on account of lower voltage, but also because it could not be compounded. Dynamo makers have long ago found out by practical experience that to produce machines of high voltage as compared to the length of wire on the armature, and machines that by reason of their rising characteristics can satisfactorily be compounded, it is necessary to work with a high magnetic density in the armature and a low density in the field. Roughly speaking, if we only take the useful lines into consideration, the ratio is from ·5 to ·6.

Before the formulæ (1 to 5) can be used for the actual determination of total exciting power as a function of the number of useful lines in any given dynamo, it is necessary to make an assumption regarding the rise of magnetic resistance with increasing density of lines. Whatever may be the mathematical connection between these two quantities, it must be of such a nature that for low densities the rise of resistance is insignificant; whilst for a certain and definite maximum density, the exact value of which depends on the nature of the iron, this rise is infinity. Amongst the formulæ which might be devised to fulfil these conditions two fairly simple expressions naturally suggest themselves—the one where the increase of resistance is made proportional to the reciprocal of the difference between saturation density and working density, and the other where it is made proportional to the tangent of an arc which represents the degree of saturation to such a measure that 90° corresponds to absolute saturation. The value of either of these two assumptions, or of any other which might be suggested, cannot be argued out on theoretical considerations, as we know as yet too little of the laws of electro-magnets. The only way is to apply either theory to machines actually tested, and then see which fits in best with practical results. In this way I have found the tangent formula to give better results than the other, and to fit actual

experiments with sufficient accuracy for practical work. Without pretending to give a scientific reason why this formula should be better than any other, it might be pointed out as at least plausible that a tangent function might enter into the relation between exciting power and magnetisation. If we assume the act of magnetisation to consist in the bringing of molecular magnets into approximate parallelism with the lines of force passing through the metal, whilst the force resisting magnetisation—which might be a passive one of molecular friction or an active one of inter-molecular attraction or repulsion—tends to turn the molecular magnets away from that position, we can consider each molecular magnet as the needle of a tangent galvanometer having a field of its own and a zero position which may possibly be different from that of its neighbours. Whatever the configuration of these molecular magnets may be, it is at least conceivable that the average angle through which they have been rotated is equal to that of a molecule which started from a position at right angles to the direction of the magnetising force, and that therefore the tangent of this angle is a measure for the current, or, rather, for the exciting power surrounding the core. The weak point of this theory is that it does not show why the angle of rotation should be proportional to the number of lines created, and therefore I do not put it forward as a true, but simply as a possible, explanation.

Whether true or not, the fact of practical importance is that we can by the use of a tangent function determine the increase of magnetic resistance at various stages of saturation in such a way as to accord with experiment, and that therefore the same formulæ can be used for the construction of characteristics of new machines. The only data (besides those taken from the drawing) which we require to know are—

1st. Z_1, the maximum number of lines which can with an unlimited magnetising power be forced through the armature core.

2nd. Z_2, the maximum number of lines which can be similarly forced through the magnet core.

These are figures which depend on the dimensions of the cores and the quality of the iron, and if we could rely upon

obtaining always the same iron, a few experiments made once for all would suffice for all future machines. Let the degree of saturation in armature and magnet be denoted respectively by σ_1 and σ_2, so that

$$\sigma_1 = \frac{z_1}{Z_1},$$

$$\sigma_2 = \frac{z_2}{Z_2};$$

then the actual resistance in the armature core is obtained by multiplying the initial resistance by

$$\frac{\text{tang.}\left(\frac{\pi}{2}\sigma_1\right)}{\frac{\pi}{2}\sigma_1},$$

and similarly for the field magnet.

From numerous experiments made with my own machines, and from data kindly supplied by some other dynamo makers, I am enabled to give the following average figures for the density of saturation to be taken as a basis when using my formulæ*:—

	Lines per square inch.
Armatures—charcoal iron wire well annealed ...	25
" " " discs " ...	22
Field magnets—hammered scrap " ...	18

The superiority of wire over discs is possibly due to better annealing, but probably to the fact that in wire cores the lines run mostly in the direction of the fibres, whilst in disc cores they run as often across the fibre as with it. The inferiority of field-magnet iron as compared to armature iron is probably due to the difficulty of thoroughly annealing large masses. I have no records of experiments made with machines having field magnets composed of thin laminæ. Perhaps some of the members present can give their experience on this very important point. It will be noticed that the figures here given, although by no means the highest which can be obtained with exceptionally good iron, are considerably higher than the maximum induction obtained

* These figures are not to be taken as generally applicable, but simply as *averages* of the usual qualities of iron now obtainable

by the important experiments made independently by Rowland, Bosanquet, and Hopkinson.

The only explanation which suggests itself to me is that the samples experimented on by those scientists were not so good as the usual commercial iron now obtainable for dynamos. Suppose, then, that we know the quality of our iron and its density of saturation. This gives us the values of Z_1 and Z_2. We now proceed as follows:—We assume a certain number of useful lines (z_1), and calculate the corresponding density (σ_1) in the armature core. The corresponding value of the function tang. $\left(\frac{\pi}{2}\sigma_1\right) \Big/ \frac{\pi}{2}\sigma_1$ (taken from a table prepared beforehand) is then multiplied with the initial resistance of the armature core (R_a), and added to the air resistance. The sum is multiplied with z_1, and thus we obtain p_1, the quantity which above was called the magnetic pressure between the pole-pieces. The leakage of lines takes place under this pressure, and to obtain the exact number of the waste lines we must know the resistance of the space surrounding the machine. This resistance cannot be calculated in the same manner as that of the air space—so much depends on the configuration of the magnets on neighbouring portions of the iron bed-plate, bearings, &c.; but from the character of the resistance of a non-magnetic medium it is evident that for similar types of dynamos the value of ρ is inversely proportional to the linear dimensions of the machine. Thus this resistance can be found by dividing a constant by the diameter of the armature. An experiment made once for all is sufficient to determine this constant for all sizes of a given type. Knowing ρ, we find the waste field $\zeta = \frac{p_1}{\rho}$, and the total number of lines created $z_2 = z_1 + \zeta$. The ratio of z_2 to Z_2 gives us the density in the magnet σ_2, and by again referring to the table we find the corresponding value of the function tang. $\left(\frac{\pi}{2}\sigma_2\right) \Big/ \frac{\pi}{2}\sigma_2$, with which the initial magnet resistance must be multiplied in order to obtain the actual resistance at that particular density. The product of this actual resistance with z_2 gives the exciting power (p_2) necessary for the field magnet alone, and the

sum of p_1 and p_2 is the total exciting power (P) necessary to produce z_1 useful lines. In this way we proceed to calculate P for various values of z_1, and, plotting the results in a curve, we obtain the characteristic of magnetisation, by the aid of which all the working conditions of the dynamo can be found. When determining the E.M.F. of the armature whilst a current is passing through it, account must be taken of self-induction, which has the effect of apparently lowering the characteristic. As this action does, however, concern more particularly the armature, and not the field magnet, it does not belong to the subject of the present paper. To show the degree of approximation in calculating the exciting power in the manner above described Figs. 2, 3, and 4 have been prepared. These diagrams contain the calculated curves for three different dynamos, whilst the points indicated by little circles are values obtained in actual test of these machines. The lower curve in Fig. 2 is the predetermined characteristic of one of my own dynamos. It shows the number of useful lines passing through the whole armature as a function of the exciting power. The upper curve shows the total number of lines created The ordinates between the two curves represent, therefore, loss by leakage. In order to enable anybody to check the correctness of these and the other curves, the data on which they have been obtained are given in a table below. The experimental points shown by little circles have for this dynamo the following values:—

z_1 =	715	1330	1490	1705
P =	3800	8600	10800	18600

By the courtesy of Messrs. Patterson & Cooper and Messrs. Crompton & Co. I have been able to test these formulæ on their machines, and the result is given in Figs. 3 and 4 respectively. The curves shown in full lines are predetermined characteristics showing the number of useful lines flowing through one-half of the armature. (These machines, "Phœnix" and "Crompton," are of the double-magnet type.) The experimental points in Fig. 3, which were kindly supplied to me by Mr. Esson, have the following values:—

$\frac{z_1}{2}$ =	207·5	594	792	910	1030	1070	1130
P =	1604	3840	5660	6900	9620	11240	12100

For purposes of comparison, a curve obtained by Fröhlich's formula has been added. This dotted curve shows values of $\frac{z_1}{2}$ obtained by using the function $\frac{P}{\alpha + \beta P}$, where α and β are constants which can be determined if two points of the actual characteristic are known. By choosing these two points near to each other a fair degree of approximation between the actual characteristic and Fröhlich's curve can be obtained, but only on that portion of the curve which lies between the points. Beyond it, on either side, the divergence is considerable. If one of the points is at $P = \infty$ (which would give, according to Fröhlich's new notation, the value of S as the reciprocal of the maximum magnetisation), the curve ought to be available from the chosen finite point up to saturation. In the diagram the finite point has been chosen at A, where P = 5,500, or about half the maximum exciting power which would be commercially profitable with this machine, since a larger power than 11,000 ampère turns would not produce any material increase of E.M.F. From the tendency of the characteristic, saturation has been assumed at $\frac{z_1}{2} = 1150$. This gives $\beta = \frac{1}{1150}$ and $\alpha = 2·32$. The dotted curve is found by using these values, and shows a considerable deviation from the points determined by experiment. By choosing the finite point A higher up the actual characteristic, a somewhat better accord between the latter and Fröhlich's curve could be obtained, but at the same time the range over which that curve can be used would be shortened.

As regards the curve of the Crompton machine (Fig. 4), the experimental points were kindly supplied to me by Mr. Swinburne, and have the following values:—

$\frac{z_1}{2}$ =	27	112	151	161	197	223	221	240	246	253	258
P =	1400	3300 and 3800	5300	5700	7700	8820	9030	10120	11300	12900	14060

The curves were found by using the following data:—

Table of Constants for the Three Dynamos investigated.

Fig.	Z_1	Z_2	R_a	R_a	R	ρ
2	2200	2200	3·7	0·40	1·18	30
3	1200	1940	4·7	0·57	0·925	18
4	300	460	2·8	1·00	2·77	47

The President.

The PRESIDENT: We have listened to a remarkably able and clear paper, and one containing points which I am sure will give rise to a very interesting discussion; but I hope that members will be brief in their remarks, so that as many as possible may express themselves upon the subject.

Professor Ayrton.

Professor AYRTON: The paper that we have heard this evening is both interesting and valuable, because it continues that very important paper that Mr. Kapp gave in this room before the Institution of Civil Engineers at the end of last year. Those present who are skilful mathematicians, and have their Clerk-Maxwells at their finger-ends, may perhaps think that Mr. Kapp is avoiding the use of the well-known mathematical theory of magnetism, and is trying to substitute some practical rough-and-ready method which cannot be very accurate. I do not look at his work from that point of view at all; since, although he has probably taken up the problem for the purpose of making better dynamos, his work is of great value from a totally different point of view—one quite apart from solving by a rough-and-ready method questions that might be solved by mathematical analysis. For he is really endeavouring to substitute a working theory of magnetising for what may be called the imaginary theory which exists in mathematical books. The mathematical theory, as many of you, at any rate, know, requires you to get inside the magnet and make a little cavity there, as if you were a mouse nibbling a bit of cheese, to see what is going on inside, and the whole thing is quite speculative. Hence I believe that the mathematical theory of magnetism has helped dynamo machine makers but little. Even the language employed in books on magnetism varies: what one writer calls "permeability" another calls "the coefficient of magnetic induction;" what one writer calls "susceptibility" another calls the "coefficient of magnetisation;"

and, what is still worse, not only are different names used for the same thing, but the same name is used for totally different things. For example, in one standard book it is said that the coefficient of magnetic induction equals $1 + 4\pi$ times the coefficient of magnetisation, while in another I find that the coefficient of magnetisation equals $1 + 4\pi$ times the coefficient of magnetic induction. It therefore seems to me that there is a double value attached to Mr. Kapp's work—first, because he will improve dynamos by what he is doing; secondly, because he will, I hope, help us to arrive at a practical theory of magnetism. Professor Ayrton.

I am very glad that Mr. Kapp has not employed Professor Rowland's curve connecting permeability and magnetic induction, which makes the permeability very small when the induction is small, then shows that it increases up to a certain maximum and then diminishes again down to nought. And my reason is not because I disbelieve in such a curve being obtained when the experiment is tried of gradually magnetising a piece of iron that has not been previously magnetised, but because in dynamos we have to deal with increasing and decreasing magnetising forces, and in such a case the permeability is practically a constant for magnetising forces up to a certain value, and then diminishes down to nothing, as Professor Rowland has it, or becomes assymptotic to the axis of magnetic induction, as Mr. Shelford Bulwell finds it.

When, at the end of last year, that very valuable paper was communicated by Mr. Kapp to the Institution of Civil Engineers, on "Continuous-current Dynamo Machines," and in which the strength of the field (z) was calculated from P (the number of ampère turns), R_a (the magnetic resistance of the air spaces between the poles of the field magnet and the iron of the armature), R_A (the resistance of the iron of the armature), and R_F (the resistance of the iron of the field magnets), these resistances were regarded as being simply in series; so that Mr. Kapp's formula* was

$$z = \frac{P}{R_a + R_A + R_F},$$

* *Proc. Inst. Civil Engineers*, vol. lxxxiii., p. 186.

Professor Ayrton.

where R_a, R_A, and R_F were simply proportional to the lengths, and inversely as the sectional area of the air space between the poles and the armature, the iron of the armature, and the iron of the field magnet.

During the discussion on this paper I stated that I did not consider that the formula expressed the actual state of things as shown by the experiments that Professor Perry and I were conducting at the time on magnetic resistance; but these experiments had not at the end of last year been carried sufficiently far to show us what was the true expression to substitute for Mr. Kapp's formula. Subsequently we arrived at it, and an account of the experiments, the object for which they were carried out, and the results obtained, formed the subject of a paper called "Note on Magnetic Resistance," announced to be read before the Society of Telegraph-Engineers on the 11th March last; but as Professor Perry and I took up the whole of that evening with the reading of two other papers, we had ourselves alone to blame that the paper in question was not read.

If magnetic resistance followed the laws of electric resistance, then, since there was a very perceptible magnetic induction, or what we will shortly call a "*magnetic flow*," through an electro-magnet excited by a current, *even when no iron armature joined its poles*, we thought that the whole air surrounding an electro-magnet might have a resistance that probably could not be neglected in problems on electro-magnetism. In fact, we did not look on an excited electro-magnet as a battery with its poles insulated, but as a battery which had its poles already joined through a rather large resistance; and the analogue of a battery with its poles insulated we regarded as an electro-magnet not magnetised by any current flowing round it. What Mr. Kapp now calls leakage we regarded as the particular magnetic flow that happened to pass through an air resistance always joining the limbs of the electro-magnet.

So that when an electro-magnet was joined, *in addition*, by an iron armature not touching its poles as is the case with the field magnet and armature of a dynamo, the assumption that the resistance of the iron of the field magnet and of the armature,

and of the air spaces between the poles of the field magnet and the armature, were all *in series* with one another we thought was probably wrong, since there was an air resistance *in parallel* with the sum of the two latter. The next question was, Did the law of parallel magnetic resistances hold? that is to say, using Mr. Kapp's letters, and calling x the resistance of the air between the limbs of the field magnet when no iron joins its poles—a resistance which did not occur in Mr. Kapp's formula—did the following equation hold true? Professor Ayrton.

$$z = \frac{P}{R_p + \dfrac{x\,(R_a + R_A)}{x + R_a + R_A}}$$

If this were true, then the neglect of the resistance x might lead to a serious error in calculations about dynamos—an error which would become greater the more the iron of the field magnet approached saturation.

To test the law of parallel magnetic resistances we did not confine ourselves to *one* iron armature to our electro-magnet, as in a dynamo; but, in the experiments we made, we used either one, two, or three iron armatures, so that the electrical analogy with our magnetic problem would be the following:—B, Fig. 1, is a battery of electro-motive force (E) and resistance r_0, and r_a, r_1, r_2, r_3, are the resistances of four conductors in parallel.

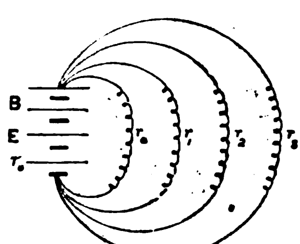


FIG. 1.

The current through the battery when all the conductors are attached is

$$\frac{E}{r_0 + \dfrac{1}{\dfrac{1}{r_a} + \dfrac{1}{r_1} + \dfrac{1}{r_2} + \dfrac{1}{r_3}}};$$

Professor Ayrton.

when only r_a, r_1, and r_2 are attached, the current through the battery is

$$\frac{E}{r_0 + \dfrac{1}{\dfrac{1}{r_a} + \dfrac{1}{r_1} + \dfrac{1}{r_2}}};$$

and so on for the combination of the conductors.

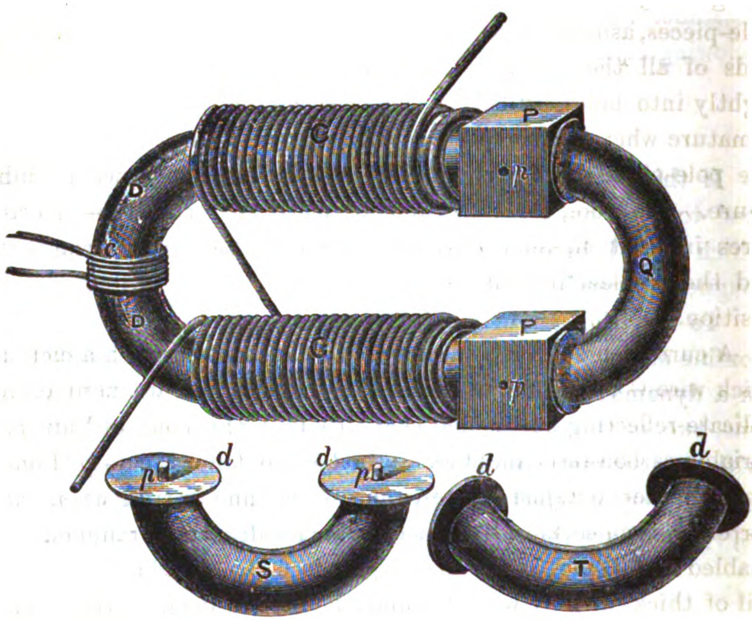


FIG. 2.

Our magnetic battery was a soft iron U-shaped electro-magnet (D, Fig. 2), with a round iron core 1 inch in diameter and about 15 inches long, fitted to a base-board. Cubical pole-pieces (P, P) made of charcoal iron, with edges $1\frac{1}{2}$ inches long, were fitted rigidly to its ends. Q, S, T are three soft iron armatures about 5 inches long, made of round bar iron 1 inch across. The ends of each of these armatures were filed so that one of the armatures could fit close against the front pair of faces of the cubical pole-pieces, a second against the end pair of faces, and the third against the back pair of faces; and the armatures and faces of the pole-pieces had corresponding numbers stamped on them for future use. As

Professor Ayrton.

it was desired in the experiments that small definite spaces should be left between the ends of the armatures and the faces of the cubical iron pole-pieces, corresponding with the air space between poles of the field magnet of a dynamo and its armature, brass discs, *d*, *d*, about one-twentieth of an inch thick, were cemented on to the ends of each of the armatures; and, to ensure each armature being always placed in exactly the same position relatively to the pole-pieces, a small brass steady pin, *p*, was inserted in each of the ends of all the armatures, and these steady pins fitted fairly tightly into holes drilled in the faces of the pole-pieces. Each armature when put in position was pressed against the faces of the pole-pieces by a fairly strong brass spring not shown in the figure. We were, therefore, able to place any one of the armatures in position, remove it far away from the electro-magnet, and then replace it at any subsequent time in exactly its original position.

A current produced by accumulators was sent through a coil of thick wire C wound round the electro-magnet, and also through a delicate reflecting galvanometer. In this circuit one of Varley's variable carbon resistances was inserted, and it was the duty of one experimenter to adjust the resistance from time to time when the current was on so as to keep it constant, which the arrangements enabled him to do to within one part in 600. In addition to the coil of thick wire C wound round the electro-magnet, there was a small coil of fine wire *c* wound round its centre, this coil being in circuit with a delicate high-resistance reflecting ballistic galvanometer. A key for opening and closing the magnetising circuit was under the control of the observer watching the high-resistance galvanometer. When the first observer, by a slight adjustment of the carbon resistance, had brought the magnetising current to a certain definite value, he gave a signal to the second observer, who then opened the key interrupting the magnetising current, and observed the first swing of the spot of light of the high-resistance ballistic galvanometer, and in this way the magnetic induction of the electro-magnet—or, more simply, the total magnetic flow—in the circuit was observed.

Care was, of course, taken that the electro-magnet was at such

Professor Ayrton.

a distance from both reflecting galvanometers that it could not directly affect them, and they were also too far separated to be able to affect one another. For a long time, however, results were obtained not perfectly consistent with one another. This was at first thought to be due to the attraction between the electro-magnet and an armature pulling the armature more or less tightly against the pole-pieces, and so slightly altering the distance separating the ends of an armature and the pole-pieces. The springs pressing the armatures against the pole-pieces were therefore altered, but still the results were not perfectly consistent, and it was found to arise from the interval of time during which the current was off after each interruption affecting the results. Hence it was found necessary to keep the current on for a definite time before an observation was made, and then to keep it off for a definite time after it was broken. Experiments were also made of keeping the current on *constantly*, except during the short time necessary to read the first swing of the needle of the high-resistance galvanometer on breaking the magnetising circuit. This method also led to satisfactory results.

The experiment was first made when the only armature to the electro-magnet was the air all round its limbs; next when armature Q was placed in position so that the magnetic circuit consisted of the iron of the electro-magnet *in series* with the air round the magnet which latter was *in parallel* with the armature Q plus the thin layer of air between the faces of the poles of the electro-magnet and the ends of the armature Q. Next, armature Q was removed and S put in its place, and lastly armature R. Next, the armatures were put in pairs near the electro-magnet—Q and R, R and S, and Q and S; and lastly all three were put close to the electro-magnet, when the circuit consisted of the iron of the electro-magnet *in series* with the air around it which was *in parallel* with the three armatures, each armature including the thin layer of air between the faces of the poles of the electro-magnet and the ends of that armature.

During the early part of this investigation all the three armatures were of the same size, and a sample is given below of the results obtained after some weeks of preliminary ex-

perimenting while the apparatus was undergoing modifications that experience showed were necessary:— Professor Ayrton.

Armature.	First Swing of the Galvanometer Needle on Breaking the Main Current.	
Air only	275·3	Each result is the mean of several concordant results.
Air and Q	453·8	
" " R	455·0	
" " S	470·3	
" " Q and R	599·3	
" " R " S	605·0	
" " S " Q	606·7	
" " Q, R, and S ...	717·8	

From the above it is clear that the resistance of armature Q is practically the same as that of R; and the calculations will be much simplified by assuming that the second and third results are equal to one another, and to the 454·4, the mean of 453·8 and 455·0.

If now we call the magnetic conductivities of the electro-magnet, the air, and the iron armatures (each armature including the thin layer of air between the faces of the pole-pieces of the electro-magnet and the ends of the armature), c_0, c_a, c_q, c_r, c_s, and the constant magnetomotive force (or ampère turns) M, we can calculate the conductivities from the first five experiments, if we assume that the law of parallel resistance holds for magnetic flow as it does for electric flow. Assuming for the present that it does, we have the following equations:—

$$\text{Magnetic flow } 273{\cdot}3 = \mathrm{M}\,\frac{c_0 \times c_a}{c_0 + c_a};$$

$$\text{Magnetic flow } 454{\cdot}4 = \mathrm{M}\,\frac{c_0\,(c_a + c_q)}{c_0 + c_a + c_q};$$

$$\text{Magnetic flow } 454{\cdot}4 = \mathrm{M}\,\frac{c_0\,(c_a + c_r)}{c_0 + c_a + c_r};$$

$$\text{Magnetic flow } 470{\cdot}3 = \mathrm{M}\,\frac{c_0\,(c_a + c_s)}{c_0 + c_a + c_s};$$

$$\text{Magnetic flow } 599{\cdot}3 = \mathrm{M}\,\frac{c_0\,(c_a + c_q + c_r)}{c_0 + c_a + c_q + c_r}.$$

Professor Ayrton.

Solving these equations, and taking M as 1,000, we have

$$c_0 = 1{\cdot}972$$
$$c_a = 0{\cdot}3200$$
$$c_q = 0{\cdot}2705$$
$$c_r = 0{\cdot}2705$$
$$c_s = 0{\cdot}2976.$$

These values for the conductivities have been obtained by assuming that the law of parallel magnetic resistances holds, and to test the truth of this we may now use these values to calculate what the magnetic flow ought to be in the last three experiments, and compare the results with those actually obtained experimentally:—

$$\left.\begin{array}{l}\text{Magnetic flow when the circuit is}\\ \text{closed by the air and armatures}\\ \text{R and S, all in parallel} \;\;\ldots\;\;\ldots\end{array}\right\} = 1{,}000\,\frac{1{\cdot}972\ (0{\cdot}3200 + 0{\cdot}2705 + 0{\cdot}2976)}{1{\cdot}972 + 0{\cdot}3200 + 0{\cdot}2705 + 0{\cdot}2976}$$
$$= 612{\cdot}3;$$

the actual result obtained experimentally was 606. For the air and the armatures S and Q, all in parallel, the same agreement holds; and, lastly,

$$\left.\begin{array}{l}\text{Magnetic flow when the cir-}\\ \text{cuit is closed by the air and}\\ \text{armatures Q, R, and S, all}\\ \text{in parallel} \;\;\ldots\;\;\ldots\;\;\ldots\end{array}\right\} = 1{,}000\,\frac{1{\cdot}972\ (0{\cdot}3200 + 0{\cdot}2705 + 0{\cdot}2705 + 0{\cdot}2976)}{1{\cdot}972 + 0{\cdot}3200 + 0{\cdot}2705 + 0{\cdot}2705 + 0{\cdot}2976}$$
$$= 729{\cdot}9;$$

the actual result obtained experimentally was 717·8. We may, therefore, conclude that for this case the law of parallel magnetic resistances holds.

If we take r_0, r_a, r_q, r_r, r_s, as the magnetic resistances of the iron of the electro-magnet, the air around its limbs, and of the three iron armatures Q, R, S, each armature including the thin layer of air separating its ends from the pole-pieces of the electro-magnet, we have—

$$r_0 = 0{\cdot}5071$$
$$r_a = 3{\cdot}125$$
$$r_q = 3{\cdot}697$$
$$r_r = 3{\cdot}697$$
$$r_s = 3{\cdot}359.$$

The first thing that we notice is the very small difference between the resistances of the three armatures, although, while the lines of force pass through the end one without any sudden bend, they must follow a path of rather sharp curvature to pass through the two side armatures. This shows that the so-called "*natural line*" of magnetic force has no meaning. There exists in the minds of some an idea that a natural line of force follows a curve like that given to a Jamin magnet, but it seems that a line of force may have nearly any shape, depending on where it comes from and where it is going to. And just as bending a wire does not alter its electric resistance, so giving a rather sharp curvature to a line of magnetic flow does not apparently increase the magnetic resistance along that path. Professor Ayrton.

We next tried if the law was true when one of the armatures was much longer than the other two, and for this purpose armature R was replaced by one about twice as long. Many experiments were made, and a sample of the results follows, each result being the mean of several:—

Armature.	First Swing of the Galvanometer Needle on Breaking the Main Circuit.	
Air alone	284·0	Each result is the mean of several concordant results.
Air and Q	459·7	
" " R...	442·1	
" " S	466·7	
" " Q and R	576·2	
" " R " S	587·1	
" " S " Q	610·0	
" " Q, R, and S ...	703·0	

The first five results were, as before, used to find the values of c_0, c_a, c_q, c_r, and c_s, and the law was tested by calculating the magnetic flow for the last case and the last but two respectively. The results obtained by calculation were 708·4 and 588·0 respectively, whereas those obtained by direct experiment were 703 and 587·1. Here again, then, the law of parallel magnetic resistances holds.

Professor Ayrton.

In all these experiments—for assistance in carrying out which we have to thank two of the students of the Central Institution, Professor Eliot and Mr. Watney—the iron was far from saturation, and the fact that the law of parallel magnetic resistance holds when the magnetic flow through the iron of the electro-magnet varies from 275 to 718 shows that the permeability must be constant throughout this range of variation of the magnetic flow.

From the preceding values of r_0, r_a, r_q, r_r, r_s, and remembering that the thin layer of air separating the ends of the iron armatures from the pole-pieces of the electro-magnet was about one-twentieth of an inch, it follows that the specific resistance of the air was about one thousand times that of the specific resistance of the iron.

It will also be observed that the resistance of one of the armatures we used, together with the layer of air, one-twentieth of an inch thick, separating its ends from the pole-pieces of the electro-magnet, is greater than that of the air round the limbs of the electro-magnet; so that less than half the total magnetic flow through the electro-magnet passes through one armature when used alone, the remainder of the flow passing through the circuit formed by the air round the limbs of the electro-magnet. This shows how very important it is not to neglect this parallel resistance of this air.

In the very valuable paper which we have heard read by Mr. Kapp to-night the idea of this *parallel* resistance of the air, which was neglected in his former paper, has now been introduced by him, but he apparently only regards it as of importance when the iron is approaching saturation; whereas the experiments made by Professor Perry and myself show that this parallel resistance of the air round the limbs of the electromagnet cannot be neglected even when the iron is far from saturation.

Mr. Swinburne.

Mr. J. Swinburne: It is very satisfactory, indeed, to find that Mr. Kapp, without knowing of Drs. Hopkinson's work in that direction, should have arrived at practically the same method of working out the characteristic curve. Mr. Kapp's method differs from Drs. Hopkinson's in one essential feature, how-

ever. They work from curves actually obtained by experimenting on iron, while Mr. Kapp uses an empirical formula. I have no faith in such formulæ as Fröhlich's or the inverse tangent, because they have obviously no sort of connection with the phenomena. One can imagine that a ring of iron magnetised all round might follow a simple law of some sort; but a magnetic circuit consisting of iron of varying section and varying quality, and partly of air spaces, with the exciting coils in one part only, obviously cannot follow any simple curve. It is no answer to say that such formulæ fit the results; nothing is easier than to get results to agree with empirical formulæ, and a man cannot help choosing the data that fit his theory. In dealing with a man of science verifying his own theory, it must be remembered that his coefficient of involuntary mendacity is about equal to that of an inventor. Mr. Swinburne.

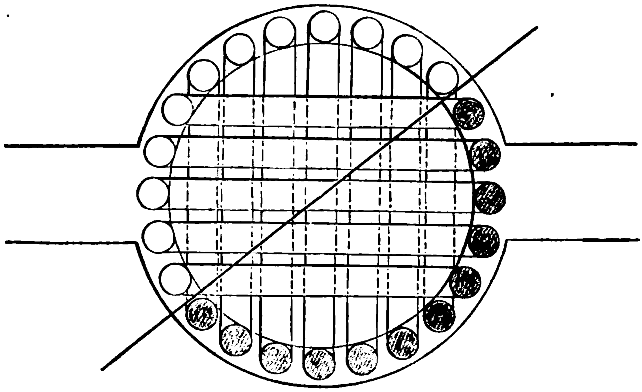
The chief drawback to methods of calculating the curves of machines is the difficulty of determining the waste field. If one wants to make a machine of a different size but approximately the same type as one already tested, there is no difficulty in knowing beforehand what the machine will do. What is wanted is to be able to foretell what a machine of quite a new type will do, so as to determine the best type without making a number of machines. Two of the chief difficulties here encountered are the cost and the ventilation. These can only be very approximately calculated. Working out the characteristics of machines already existing is, like calculating field-magnet windings, a mere amusement. If the waste field is anything like what Professors Ayrton and Perry find it, this factor is almost too great to be left to guesswork.

I should have preferred to have spoken after Mr. Crompton, as I have worked so much under him that I have absorbed many of his ideas, and may say many things that he would say better.

The cross-magnetisation of an armature may be shown diagrammatically. Take the case of the drum armature, as it is simplest:—

Let the oblique line be the diameter of commutation, and let the shaded circles represent the wires with the current flowing

Mr. Swinburne. one way, and the blank circles the return. Then, instead of the real end connections, we can connect the wires across in two sets, one with the coils in horizontal and the other in vertical planes.



Those in the horizontal plane represent the armature coils opposing the induction, while those in the vertical plane are acting at right angles to it.

As to Professor Rowland's curve: if it were true, a shunt machine would not excite itself. If the curve of induction of a machine be drawn, with ampère turns as abscissæ and volts as ordinates, the ampère turns on the shunt may be drawn as a line starting from the origin, and the machine will then give the electro-motive force corresponding to the point where the curve crosses from above to below this line. If the curve really started below this line, the machine could not excite itself.

Mr. Kapp has raised an interesting question as to the small particles of iron being like little needles in a tangent galvanometer. But if the force needed to turn each round were constant, it would be a case of a secant galvanometer. There would also be a number of particles which were already nearly in the right direction, or nearly opposed to the induction, which would not be affected. The resulting relation between the displacement and magnetising force works out a complicated equation.

Mr. Crompton does not use bar field magnets to avoid induced currents in the pole-pieces, but because they can be

more easily rolled. There is no continuous current induced in pole-pieces. This idea started in France; but, though the armature revolves, the field in it remains stationary. Of course there may be a tendency to the induction of small alternating currents, as pointed out in Drs. Hopkinson's paper; though they seem to have exaggerated this defect. Each section is only supposed to be short-circuited long enough to allow its current to reverse, and to increase to its normal value just when the toe of the brush leaves the commutator segment. The self-induction of the armature makes the direction of the armature induction stationary. In such a machine as the Brush, of course, the Foucault currents become serious. Mr. Swinbu

Mr. Crompton has introduced the practice of having very thick field magnets, so that he gets what he would call a low-resistance field; or, as Dr. Hopkinson might say, a disposition in which the line integral taken round that part of the path is insignificant in comparison with the line integral taken round any complete cycle interlinked with the magnetising circuits. In the Edison-Hopkinson machine the field is apparently as strongly magnetised as the armature. Mr. Crompton's practice is quite different; iron is cheaper than copper, so it is better to increase the section of the field magnets and get the armature more strongly magnetised. In the "Manchester" machine Mr. Crompton's practice seems to be followed, with the remarkable result that the makers get nearly half as much induction again in the armature. Of course this is partly due to the small section of the armature relatively to the polar surface. The Edison-Hopkinson machine appears to have a magnetisation of very nearly 1,000 C.G.S. units, against nearly 1,430 in the "Manchester" dynamo. The magnetisation is here taken, not merely because it is the cardinal point in dealing with saturated iron, but because another unit is brought in.

[*Added after Discussion.*—The question has been asked, What induction can be got in iron in a dynamo machine? Messrs. Crompton & Co. have lately made a small machine which had an induction of 22,350. This was got by very strongly exciting the fields to get the maximum starting torque as a motor. The

Mr. Swinburne. Bürgin machines at the Exhibition this year had an induction of $2{\cdot}48 \times 10^6$ Kapp lines per acre, or 20,600 C.G.S. The armatures were made of rings of fine soft iron wire. It is here assumed that there is no induction in the little air spaces between the wires.

I do not quite understand from his article quoted in the *Electrician* what Mr. Bosanquet is doing. It might be interesting to determine the relation of the electro-magnetic measurements in use with the fundamental units by measuring the torque of a dynamo, and by testing it in the ordinary way. There are many ways of which this might be suggested as the prototype. It is assumed in dynamos that the induction is uniform over a section through, say, the field magnets; but Mr. Bosanquet's experiments seem to show that the pull needed to separate a magnet is greater than the calculated. By taking the force to pull a magnet apart the square of the induction is integrated over the section; so if the pull is greater than calculated the induction is not uniform, as that would give the minimum pull. Could the distribution of the induction be determined by such experiments?

Dr. Hopkinson seems to have misunderstood me. I do not advocate cheap machines; quite the reverse. In a little book published in 1883 I point out that "the general practice of electrical engineers is to put down plant too small for the duty to be done;" and after working a dynamo out as example, I say that "the best price is such that if it is reduced the increase of cost per year by loss of energy is greater than the yearly saving of deterioration and interest due to the reduction; and if increased, the deterioration and interest on the increment is greater than the yearly saving due to the greater efficiency of the machine."]

Mr. Fricker. Mr. G. C. Fricker: I should like to ask Mr. Kapp a question in regard to P, the figure he takes for the exciting power, in ampère turns. It seems to me that in any wire conveying a current there is a magnetising power which is exercised in creating lines of force as a sort of sheath around that wire, and by bending the wire into a closed curve the lines of force are induced to pass in one direction through the interior, and so a magnet is produced. Viewing the matter in that way, it seems

to me that the magnetising power is simply a product of the current and length, and by merely making two turns in the same length of wire I fail to see how the exciting power can be doubled. I should be very glad if Mr. Kapp would explain that point to me. Mr. Fricker

Mr. R. E. CROMPTON: I think that we English electrical engineers ought to feel proud of the paper now before us, as well as of Dr. Hopkinson's on the same subject, recently read before the Royal Society. In these days, when the advance of electrical engineering has been so greatly retarded in this country by prohibitive legislation, it is a grand thing that this Society should be able to put on record that the investigations into the true theory of the dynamo machine are being carried much further here than abroad. Mr. Crompton.

M. Deprez has lately given to the French technical journals a paper in which he claims much of the best part of Dr. Hopkinson's work. He is not content with claiming the invention of the characteristic curve of the dynamo, the credit of which we Englishmen believe to be Dr. Hopkinson's, but he is now claiming the short stumpy field magnets which we know were first introduced by Dr. Hopkinson in his improved form of the Edison dynamo. No one who now reads Dr. Hopkinson's and Mr. Kapp's papers can doubt that the idea of reducing the resistance of the magnetic circuit really originated in this country.

As I do not intend to criticise this paper from a mathematical standpoint, I propose to say a few words for the comfort of those electrical engineers who, like myself, are not sufficiently skilled mathematicians to work out the design of a dynamo in the manner given in the present paper.

There are, I daresay, many people present who, like myself, would never have designed a successful dynamo if it had depended on the abstruse and difficult mathematical formulæ which are now put before us by Mr. Kapp. I, for one, have done most of my designing by the graphic method—that is to say, by eye. My practice has been to make designs and models, and introduce variations from time to time, constantly correcting these designs by eye. I am quite certain that the idea of reducing the resist-

npton. ance of a magnetic circuit first occurred to me, as it must have done to many others, when examining designs on the drawing-board. My personal experiences in this matter are as follow.

I hope Mr. Kapp will forgive me if I tell some stories out of school. Mr. Kapp was with me at the time that much of the improvement that was introduced in dynamo design was being worked out at our works. At the start I was making the Bürgin form of dynamo having cast-iron field magnets, certainly very much over-saturated, and with armature cores having a very small section of iron. I met with certain difficulties when attempting to make large Bürgin machines, and in casting about for the best method of improving the design I often wondered why, in some respects, the performance of the Siemens machine was so good, and I noticed as one peculiarity of that machine the large section of iron in the armature core. I then attempted to increase the iron of the armature of our machine, but found it difficult as long as I maintained the Bürgin form of core. At that time Mr. Kapp certainly did not approve of my desire to use a greatly increased quantity of iron. He then said that it could be shown mathematically by calculus that the iron core ought to bear a certain proportion to the winding in order to get the maximum output and the maximum efficiency. In spite of this, I took advantage of Mr. Kapp's absence at Vienna to design a machine having what he called an absurd amount of iron in both armature and field magnets; that is to say, that whereas up to that date it had been the custom to employ in Gramme rings a radial depth of the core only about one-tenth of the diameter, I increased the depth to one-fourth the diameter—that is to say, to half the radius—and I increased the cross section of my field magnets in proportion to this. This machine was completed shortly after Mr. Kapp's return, and we both of us were greatly pleased with the extraordinary increase of output, and many other good qualities, which appeared to come from the use of so much iron and so little winding. Sir William Thomson, who just then visited our works, was greatly struck with what he called the "extreme activity" of this experimental dynamo. Dr. Hopkinson had not then made public what he was doing with the Edison

dynamo, but when he did so I saw at once that we had been working on the same lines, and that I had been doing for the ring armature type of dynamo what he had done for the cylinder or drum type. It was impossible to look at the design of my experimental dynamo without the idea at once occurring to one how much we had reduced the resistance of the magnetic circuit; and from that time dates Mr. Kapp's conversion to what I may call the modern practice of dynamo design. The valuable work he has now laid before us shows how thoroughly he has appreciated this central idea of reducing the resistance of magnetic circuit. Mr. Crompton.

I here cannot help saying that after all, with the sole exception of Dr. Hopkinson, the mathematicians have not led the way in this question of dynamo design, but have really followed those who designed on the drawing-board by their eye.

I wish here to point out the curious fact which Mr. Kapp and Professor Ayrton have called attention to, and in which really lies the kernel of the difficulty of dynamo design.

Students of electrical engineering find, as a rule, that they make extraordinary progress in the study of electrical phenomena—really because the laws which govern the flow of electricity are so very simple, and the corrections which have to be introduced into their calculations are so few. Electricity, to use a French phrase, is so easily "canalised," or conveyed through insulated conductors, with little or no loss by leakage, into the surrounding medium, that most of the problems which present themselves to the electrical engineer are purely arithmetical ones; whereas students attacking the ordinary problems which present themselves in considering the heat engines (such as the steam, gas, and hot-air engines) find themselves at every turn confronted by difficulties arising from the fact that heat cannot be "canalised." It is always escaping or being dissipated in directions where it is not wanted, and the corrections that have to be introduced, and which are due to these losses, are so numerous and so difficult to allow for as to require years of study and experience before anyone can hope to be a successful designer of such engines. Mr. Kapp and Professor Ayrton, in their study of the flow of magnetic lines through a magnetic

Mr. Crompton.

circuit, appear to have met for the first time with analogous difficulties. The lines of force, instead of being wholly "canalised" in the magnetic circuit provided for them, will insist upon straying out into the surrounding medium—the air; the difficulty of calculating for the leakage of lines in this surrounding medium appears to me very analogous to the difficulties of the heat losses through the walls of the cylinder of the heat engine, and can only be allowed for after much patient experiments and observation.

Mr. Siemens.

Mr. ALEXANDER SIEMENS: Without going into the mathematical discussion of the subject, I would draw the attention of mathematicians to the fact that the dynamo machine should be also looked at from a mechanical engineer's point of view, and treated like a steam engine in so far that dynamo machines must not be used to the utmost of their power. Even if thereby a little is lost in the theoretical efficiency, very much is gained in the practical duration of the life of the machine. Briefly, if mathematical considerations are applied to the construction of dynamo machines, a factor of safety should be brought in, just in the same way as is the practice in the construction of steam engines.

Mr. Esson.

Mr. W. B. ESSON: There are a few remarks I wish to make upon Mr. Kapp's very interesting paper. In the first place, I should like to have from Mr. Kapp some data regarding the comparative exciting force required when discs are used, and when iron wire is used, for the armature cores. I believe Mr. Kapp uses iron wire; others use discs; and, given for armatures of the same length the same area of iron wire and the same area of disc, with the same air space and the same section of field magnets, there is some ratio between the comparative excitements required which it would be exceedingly useful to know.

On page 3 of his paper Mr. Kapp refers to the necessity for making the cross section of the field magnets very much greater than the cross section of the armature; but I should like if Mr. Kapp would tell us the exact ratio he considers the one ought to bear to the other. Disregarding the proportions adopted in machines having armatures of the drum type, we find in machines

having ring armatures the greatest difference in the proportions adopted by different makers. Mr. Esson.

In the "Manchester," "Phœnix," and "Victoria" machines the area of the armature core is to the area of the field magnets as 2 : 3. In Mr. Crompton's machine and in Mr. Kapp's machine the area of the core is smaller than in any other, being only about half the cross section of the field magnets. In the Goolden and Trotter and Elwell-Parker machines the cross section of the armature closely approximates that of the field magnets. Now there must be some proportion which is the most economical. It seems to me that when the magnets are very large proportionally to the armature core a field is created of which only a fraction can be utilised. A case illustrating this came under my notice in which, when the cross section of the armature core was doubled, it was found that the lines of force flowing through the armature core were increased by 90 per cent. The field magnets were not altered, nor was the excitement increased. One armature was simply substituted for another, with the result I have mentioned. That proved that excess of iron in the magnet produced no corresponding advantage beyond a certain point; the question remained, Where was that particular point situated? For some time past I have been reducing the section of the field, or rather, as I prefer to put it, increasing the section of the armature. The result has been an improvement for every additional bit of iron put into the armature core. No limit has been yet reached, and at present the core of the armature is to the field magnet core in the "Phœnix" machines as 3 : 4.

It struck me, while Mr. Kapp was reading his paper, that the thing which was the unknown quantity was the amount of leakage. Mr. Kapp says, and doubtless truly, that the leakage constant can be determined and used for the same type of machine over and over again. Remembering that machines of similar type have their linear dimensions rarely varying in strict proportion, I am afraid that the leakage constant would have to be determined if great accuracy is desired for each *size* of machine as well as for each *type*.

Mr. Kapp: In the 3 : 4 do you take into account the double magnetic field?

Mr. Esson.

Mr. W. B. Esson: Yes, I do take it so. The section of the armature core is to the section of one horse-shoe as 3 : 4.

The President.

The President: It is evidently too late to bring the discussion to a close this evening, as there are still several members who desire to make observations. I propose, therefore, to adjourn the discussion to the next meeting; but this will not prevent my moving, as I do now with much pleasure, that the thanks of the meeting be accorded to Mr. Kapp for his valuable and interesting paper.

The motion was unanimously carried.

The meeting then adjourned.

The One Hundred and Fifty-ninth Ordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, November 25th, 1886—Professor D. E. HUGHES, F.R.S., President, in the chair.

The minutes of the previous meeting were read and approved.

The PRESIDENT: To-night we continue the adjourned discussion on Mr. Kapp's paper, and as on so interesting a subject a full discussion is likely to take place, I shall be glad if intending speakers will advise me, that I may arrange their names with the view of calling upon them in order. The President.

Professor GEORGE FORBES referred to the previous attempts made to bring before the electrical world methods to predetermine, to a certain extent, the characteristic of a dynamo from its design, and foremost among those attempts he pointed to the work of Frölich, who started with the assumption of a formula which tallied with the characteristic of a series-wound dynamo and which had been analytically investigated by Mr. Rücker in a paper before the Physical Society. In such work it always seemed to him that there was an attempt to jump too suddenly at the final result, viz., to find a formula which should agree directly with the working of a series-wound dynamo; while it was probable that a much nearer approach to the truth would be obtained if the efforts were directed to the determination of the electro-motive force at a given speed, or the intensity of the total induction through the armatures when a given current in ampère turns went round the field magnets. Such a line Mr. Kapp had taken up, and it had also been followed in the paper by Dr. John and Dr. Edward Hopkinson before the Royal Society—a paper which he (Professor Forbes) pointed out would have been properly brought before the Society of Telegraph-Engineers, seeing that it was essentially of a character suitable to that Society, and also because Dr. John Hopkinson was a Vice-President of that Society. Mr. Kapp stood in a prominent position in the history of the problem from the formula Professor Forbes.

Professor Forbes.

he had presented in a paper before the Institution of Civil Engineers last year, and in which he had shown that the induction passing through the armature might be represented in form of the magnetising force divided by the magnetic resistance. The laws governing magnetic induction in space were similar to those governing the distribution of an electric current, similar to those which govern the distribution of heat, and also similar to those which govern the motion of an incompressible fluid. We generally know the path followed by electric currents, because they are generally led through a wire conductor, and this facilitates their calculation. When we know the path of magnetic induction its calculation also becomes easy. Having so far referred to the past, he related his objection to certain points in Mr. Kapp's paper, and said that, in discussing the paper before the Institution of Civil Engineers last year, he had implored Mr. Kapp to abandon that most awful combination of centimètre-gramme-seconds units, and of inches and minutes, which was included in z of his formula. It was the most incomprehensible, brain-wasting invention that could have been devised, and it was becoming utterly impossible for any man not possessing very great leisure to be able to read intelligently Mr. Kapp's papers. Mr. Kapp might himself have become accustomed to the combination, but it prevented the intelligent reading of his paper by other people. Brain was to most people a limited quantity, and it was almost criminal of a man in Mr. Kapp's position to impose a wasteful destruction of the brain in order to decipher his papers. Professor Forbes himself had not had sufficient time to interpret the exact meaning of two parts of the paper under discussion. Mr. Kapp had said that the numeric 1,440 represented the specific magnetic resistance of air in the arbitrary system of measurement he had adopted, but he had not found sufficient courage to prove whether it was so or not. Further, Mr. Kapp said that the initial specific magnetic resistance of iron was given by the numeric 2; that, also, he had not examined, and it might be right or wrong. But certainly one of the two figures must be wrong, if not both; for it was known that the permeability of iron in its initial stage of magnetisation

was really more than 720. That affected the whole reasoning in the paper; and while Mr. Kapp had satisfactorily introduced a formula which gave a representation of the physical facts, he was inclined to think that the formulæ were not general, because they were based on erroneous values of parts of the quantities, and it was only by a happy picking out of different constants that Mr. Kapp had succeeded in getting a curve to suit his observations. The formula $Z_1 = P$, divided by the resistance of the air space plus the resistance of the field magnets plus the resistance of the armature, clearly was not based on what were known as magnetic resistances, neither did P represent what was known as the magnetising force, but really the number of ampère turns. The true magnetising force was $\frac{4\pi}{10} \times$ number of ampère turns. He might be wrong in the impression that the formula led to erroneous conclusions, but he certainly was inclined to think that it did so, especially when he noticed that the value of the magnetic resistance of the air in the case of certain dynamos that Mr. Kapp had deduced was enormously larger than that of the polar space between the armature and the field magnets. In the paper by the Messrs. Hopkinson that proportion was by no means large, and the conductivity of the field of waste lines of induction was very comparable indeed with the conductivity of the air space between the poles. Mr. Kapp's paper of last year had, he was sure, led a great number of people to study the subject more fully than they had done before; it had certainly led him to do so. Professor Forbes.

The speaker then continued as follows:—When I wish to calculate from a new design of a dynamo what number of ampère turns is required to produce a stated E.M.F. at stated speed, I first calculate the total induction (I) *in the armature required for this E.M.F., and the problem is reduced to finding the ampère turns required to give this induction. The magnetic resistance of the two air-and-copper spaces between the pole-piece and armature

* Mr. Kapp (besides many others) has shown how to do this in his paper last year read before the Institution of Civil Engineers.

Professor Forbes.

core is the chief resistance which has to be overcome. Call this resistance R_a. It is approximately equal to twice the distance between a pole-piece and armature core divided by the area of a polar face. The ampère turns (n C) required to overcome this magnetic resistance and to give a total induction = I are given by $I \times R_a = \frac{4\pi}{10} n C$, where C is measured in ampères. Dividing I by the area of section of a magnet limb, we get the rate of induction in the limbs, and if we know the quality of our iron we know the value of μ corresponding to this induction. The magnetic resistance of magnet limbs (R_f) is the mean length of the induction path through the limbs divided by μ times the sectional area. The ampère turns (n'C) required to overcome this resistance and give an induction I are given by $I \times R_f = \frac{4\pi}{10} n'C$. Hence the total number of ampère turns required to overcome magnetic resistance of air-copper space and limbs is

$$N\,C = (n + n')\,C = \frac{10}{4\pi} I\,(R_a + R_f).$$

[If we include also the armature resistance, we obtain a formula resembling Mr. Kapp's in character, viz.,

$$P = Z_1\,(R_a + R_a + R_f)]$$

But we now know that the total induction in the field magnets is greater than in the armature in some ratio (ν to 1), owing to some induction passing through surrounding space, which induction is not utilised. Hence the true number of ampère turns becomes $N\,C = \frac{10}{4\pi} I \cdot R_a + \frac{10}{4\pi} \nu\, I \cdot R_f$, where we know everything except ν, and when R_f is now computed from a value of μ corresponding to a total induction ν I. Going through the whole calculation, for each value of the E.M.F. we find a different value of N C., and hence we can plot the characteristic curve of the dynamo.

The process I have described is a little slow perhaps. It resembles that described by J. and E. Hopkinson (*Trans. R. S.*, 1886) in their first approximation, but is quite devoid of the rare beauty of the method propounded by these authors, who plot a

characteristic curve for each part of the magnetic circuit, and sum them up so as to obtain the final characteristic. Professor Forbes.

I would not have thought a description of my own methods of the least value, since the above memoir was published, had I not gone a step farther and completed the process of calculating the characteristic of a dynamo. This time last year, when Mr. Kapp read his paper before the Institution of Civil Engineers, my methods were imperfect; but a comparison with Mr. Kapp's experiments showed me that there was some potent element omitted in my calculations tending to diminish the induction, and I soon saw that it was due to what has been looked upon as magnetic conductivity of air by some, and free magnetism by others. I then resolved to extend the approximate methods of calculating induction, which assume a knowledge of the paths of magnetic induction, and apply them to the air circuit as well as to the magnet circuit, and so to calculate the factor, ν, and I succeeded beyond my expectations, and found that with a knowledge of the magnetic qualities of a special iron I could determine the number of ampère turns required to produce any induction in any form of dynamo. I then proceeded to the design of an instrument for determining the quality of iron by examination of a solid block of it, and intended to offer the complete investigation to the Society of Telegraph-Engineers. It is only quite lately, however, that my experiments have led me to feel confident of success in this final detail, and I hope before long to describe the instrument to the Society. In the meantime I will proceed to the calculations of induction through air. I will commence with three lemmas referring to cases which occur very generally.

Lemma I. The magnetic conductivity of the air space between two parallel planes of nearly equal area is the mean of the two areas divided by the distance between the planes, the measurements being made in centimètres.

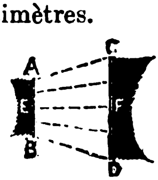


FIG. 1.

Professor Forbes.

Lemma II. If the induction in an air space between two equal rectangular areas similarly situated in the same plane be assumed to be along semi-circles with the medial straight line as the line of centres, the magnetic conductivity of that space is $a\int\frac{d\,r}{\pi\,r} = \frac{a}{\pi}\log._{\epsilon}\frac{r_2}{r_1}$, where r_1, r_2 are the distances from the medial line to the nearest and farthest edges respectively of the rectangular areas, and a is the width of each rectangle.

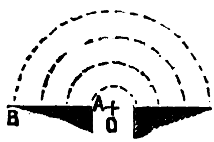


Fig. 2.

Lemma III. If the induction in an air space between two equal rectangular areas similarly situated in the same plane be assumed to be along quadrants with neighbouring edges of the planes as lines of centres, the quadrants being connected by straight lines, the magnetic conductivity of that space is $a\int\frac{d\,r}{\pi\,r + b} = \frac{a}{\pi}\log._{\epsilon}\frac{\pi\,r_2 + b}{b}$, where r is the width and a the depth of each rectangle, and b is their distance apart.

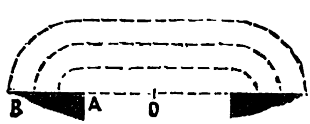


Fig. 3.

By help of these three lemmas all ordinary types of dynamos, such as Hopkinsons', Crompton's, Siemens', Phœnix, Elwell-Parker, and others, can be calculated by fairly strict rules. The Mather & Platt, Kapp, and some other machines, require some judgment. From the experience and confidence gained in dealing with the simpler class, I have perfect confidence when I apply the methods to the more difficult class. But I will not offer an example of the latter, because you could not be sure that I was not manipulating my methods to get the required results. It will be more convincing to take the Edison-Hopkinson machine, about which complete details are given in the *Phil. Trans.* this

year, because as we proceed you can see that it is impossible for me to be unfair. Professor Forbes.

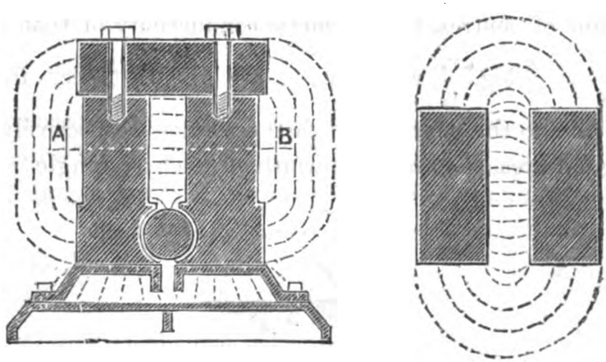


Fig. 4.

Two sections of the machine are shown in Fig. 4—one in a plane perpendicular to the axis; the other cutting the magnet limbs at right angles by a plane parallel to the axis. The dimensions of the parts are given below:—

	cms.
Length of magnet limb	45·7
Width " "	22·1
Breadth " "	44·45
Distance between centres of limbs ...	38·1
Bore of fields	27·5
Depth of pole-piece	25·4
Width of pole-piece parallel to shaft	48·3
Width of gap, pole-piece to bed-plate	(13·7) 12·7
Diameter of armature core	24·5
Length of core over end-plates ...	50·8

A zinc support separates the poles from the iron bed-plate.

I. The first source of magnetic leakage in this machine is from the ends of the pole-pieces to the iron bed-plate, and thence to the other pole-piece. The magnetic resistance of the bed-plate itself is negligible. The magnetic conductivity (K_1) of this air space is half the magnetic conductivity of the air space

Professor Forbes.

between one pole-piece and half of the bed-plate. Hence (by Lemma I.).

$$K_1 = \frac{\tfrac{1}{2}\,(\text{area of end of pole-piece} + \text{half the area of top of bed-plate})}{2 \times \text{width of gap between pole-pieces and bed-plate}}$$

$$= \frac{\tfrac{1}{2}\left[(25{\cdot}4 \times 48{\cdot}3) + \tfrac{1}{2} \times 54{\cdot}3 \times 70)\right]}{2 \times 12{\cdot}7} = 63.$$

The magnetic resistance from pole-piece to pole-piece, through the armature, is almost wholly due to the two air spaces. The magnetic conductivity of this air space I take as being K = 524 by the calculation to be given presently, thus:—

$$x_1 = \frac{\text{induction outside armature, from ends of pole-pieces}}{\text{induction through armature}} = \frac{63}{524} = {\cdot}12.$$

II. The next source of magnetic leakage is across the limbs. The chief part of this is between the interior faces of the two limbs. There is also some magnetic induction from the sides of one limb to the sides of the other limb. I assume the lines of induction in the latter part to be semicircles, as shown by dotted lines in Fig. 4. I treat this part by Lemma II. The space included between the two limbs and the smallest of the semicircles I treat by Lemma I. The average width of this space is the mean between the breadth of limb and breadth of limb plus diameter of smallest circle. Multiplying this by the height or length of limb, and dividing by distance between limbs, we get magnetic conductivity

$$K_2 = \frac{\tfrac{1}{2}\,(44{\cdot}45 + 57{\cdot}45) \times 45{\cdot}7}{13} = 178.$$

For the semicircular lines we get, by Lemma II.,

$$K_2' = \frac{45{\cdot}7}{\pi} \log_{\epsilon} \frac{28{\cdot}6}{6{\cdot}5} = 21{\cdot}5$$

on each side of the limbs, and total conductivity of air space between limbs is

$$K_2 + 2\,K_2' = 221.$$

At or near the yoke the magnetic force from limb to limb is zero; at the other end of the limbs it equals the magnetic force acting through the armature. This air conductor may be looked upon as a shunt joining the middle points of the two limbs. [Added Dec. 29.—If the magnetic difference of potentials between limbs

Professor Forbes.

be $\dot{a}\, y$ where y is the distance from the yoke and if $\frac{\mathrm{R}}{dy}$ be the magnetic resistance of an elementary section of air space from limb to limb, then R is constant and the total magnetic induction from limb to limb is $\int_o^l \frac{a\, y\, dy}{\mathrm{R}} = \frac{a\, l^2}{2\,\mathrm{R}}$ where l = length of limb. This is equal to

$$\frac{a\,l}{2} \Big/ \frac{\mathrm{R}}{l} = \frac{\text{magnetic difference of potential between the middle of the limbs.}}{\text{total magnetic resistance of air space between limbs.}}\Bigg]$$

Let r_1 be the magnetic resistance of the yoke and half the two limbs, = approximately the magnetic resistance of remaining halves of limbs and of the path of magnetic induction through the armature; let r_2 = magnetic resistance of polar air spaces; and let $r_3 = \frac{1}{\mathrm{K}_2 + 2\,\mathrm{K}_2'}$ be the magnetic resistance of the shunt. Then, computing as if we were dealing with electric currents, with equal electro-motive forces in the limbs on each side of the shunt placed across the middle of the limb, we find

$$x_2 = \frac{\text{magnetic induction from limb to limb}}{\text{magnetic induction through armature}} = \frac{r_2}{r_1 + 2\,r_3};$$

and since r_1 is always very small indeed compared with $2\,r_3$, we have simply

$$x_2 = \frac{r_2}{2\,r_3} = \frac{\mathrm{K}_2 + 2\,\mathrm{K}_2'}{2\,\mathrm{K}} = \frac{221}{1048} = \cdot 21.$$

III. We must now consider the sides of the pole-pieces. In applying Lemma II. we may take the pole-pieces as blocks 25 cm. high and 20 cm. wide and 48·3 cm. long separated by a distance = 13 cm. Here $r_1 = 8$, $r_2 = 28$; whence $\mathrm{K}_3 = \frac{48\cdot 3}{\pi}\log._\epsilon \frac{28}{8} = 19\cdot 2$ on each side of the pole-pieces, and

$$x_3 = \frac{\text{induction outside armature from sides of pole-pieces}}{\text{induction through armature}} = \frac{38\cdot 4}{524} = \cdot 073.$$

All other sources of leakage are comparatively unimportant, but the following is computed to make quite certain:—

IV. For the induction from the back of the pole-pieces to the

Professor Forbes.

yoke I apply Lemma III. Here $r = 25$, $a = 48{\cdot}3$, $b = 45{\cdot}7$, $K_4 = \frac{48{\cdot}3}{\pi}\log._\epsilon \frac{\pi \times 25 + 45{\cdot}7}{45{\cdot}7} = 15{\cdot}3$ for each of the two pole-pieces in magnetic series; whence

$$x_4 = \frac{\text{induction from one pole to yoke and back to other pole}}{\text{induction through armature}} = \frac{7{\cdot}6}{524} = {\cdot}0014.$$

Summing up, we have

$$\nu - 1 = x_1 + x_2 + x_3 + x_4 = {\cdot}12 + {\cdot}21 + {\cdot}073 + {\cdot}001 = {\cdot}40.$$

Let us return for a moment to the value of $x_3 = \frac{r_2}{r_1 + 2\,r_3}$. How does this vary with the induction? I have assumed that the specific magnetic resistance of the iron of the armature is equal to that of the field magnets. This assumption is sufficiently exact, and leads to the conclusion that ν is constant for all values of the magnetic induction.

The result of all these calculations is that

$$\nu = \frac{\text{total induction}}{\text{induction through armature}} = 1{\cdot}40.$$

We may be quite certain that this is not too large a value. Doctors Hopkinson find it by experiment to be 1·32, but they measured the total induction at the middle of the limbs instead of near to the yoke. This just accounts for the difference, 0·08. The Hopkinsons' calculated curve, using the value 1·32, differs from observation by a quantity which increases with the induction. They supposed this to be due to a variation of ν with induction. There is, however, no sensible variation of ν unless the magnetic induction of the armature were pressed far beyond the limits of observation. I find, however, that by using the constant 1·40 in place of 1·32 for ν, the curve obtained coincides well with Hopkinsons' observations. [Added Dec. 29.—The value of ν however varies along the magnet limbs. For greater accuracy ν, and hence n C, should be calculated for the different parts, and the values of n C should be added together.] I have been using these methods now for nine months, and knew that they gave good results; but I never had access to such complete details as the Hopkinson memoir gives, and this is the first conclusive proof I have had.

I may make some remark on the Hopkinsons' value for the area of the air space, which is larger than that of the polar surfaces facing the armature. I have computed this separately

Professor Forbes.

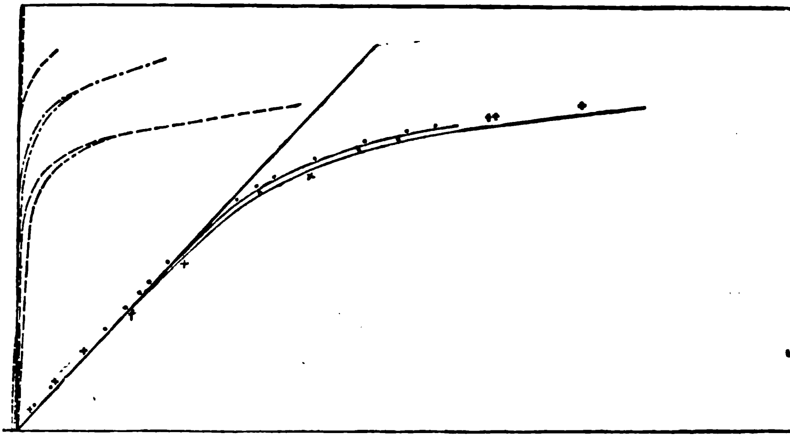


FIG. 5.—Characteristic curve (for increasing and decreasing current) of the Edison-Hopkinson dynamo, predetermined entirely from the design and quality of iron, and compared with the observations of Hopkinson. Crosses indicate increasing current, dots decreasing current.

on the principles I have given, determining approximately the induction in the armature due to the sides and ends of the pole-pieces. The value of the induction obtained in Hopkinsons' first approximation, when the area is taken as half the sum of areas of pole-pieces and of armature facing pole-pieces, is 483. In their second approximation they corrected this by their observations, and obtained 533. My calculations give me 525. I will now show how I calculated the conductivity of the air spaces occupied by lines of induction passing through the armature.

The induction through the armature consists of several parts—

(i.) Induction through the air space between the pole-pieces and armature.

(ii.) Induction from bottom of pole-pieces to armature.

(iii.) Induction from limbs to armature.

(iv.) Induction from ends or sides of pole-pieces to armature.

Indicate the conductivity of air spaces where these several parts of the induction occur, by the symbols k_1, k_2, k_3. k_4.

Professor Forbes.

$$k_1 = \frac{\text{arc of the pole-piece} \times \text{width of pole-piece}}{2 \times \text{distance from pole-piece to armature}} = \frac{\frac{\pi \cdot 129}{360} \times 24 \cdot 5}{2 \times 1 \cdot 5} \times 48 \cdot 3 = 443.$$

To find k_2 I use a slight modification of Lemma II.

$$k_2 = \tfrac{1}{4}\int_0^{6 \cdot 3} \frac{\text{width of pole-piece}}{(\pi - \alpha)\, x + t} = \tfrac{1}{4}\int_0^{6 \cdot 3} \frac{48 \cdot 3\, dx}{\frac{129^0}{180} x + t},$$

where x is measured along the surface of the armature core from the radius which cuts the edge of the pole-piece, and $t =$ distance between armature core and pole-piece $= 1 \cdot 5$ cm. The distance along x to the centre of the space between the horns of pole-pieces is $6 \cdot 3$ cm.

Whence $k_2 = 21 \cdot 7$.

k_3. The lengths of lines of induction is half of what they are in k_2; whence $k_3 = 43 \cdot 4$.

To find k_4 I have supposed the iron of pole-pieces and armature core to be separated by straight air spaces $1 \cdot 5$ cm. thick, drawn from horn to horn of each pole-piece. Applying Lemma I.,

$$k_4 = \text{depth of pole-piece} \times \int_o^{6 \cdot 3} \frac{d\,r}{\pi\, r} = \frac{25}{\pi} \; log. \frac{6 \cdot 3}{\cdot 75} = 16,$$

whence $K = k_1 + k_2 + k_3 + k_4 = 443 + 21 \cdot 7 + 43 \cdot 4 + 16 = 524$. The Brothers Hopkinson used the value 535, which is practically identical with my value. They do not say how they obtained this value. It must have been either by trusting their judgment or by examination of the curve obtained after observations had been made. This is certainly the most difficult part of all the methods of approximation, but judgment is also required to approximate to the forms of the lines of induction through the limbs, still more so through the armature. The judgment required for determining the effect of waste field is far less liable to error.

Neither Fröhlich, Kapp, nor the Hopkinsons show how to calculate ν, or make any attempt to do so. The Hopkinsons do so by experiment after the machine is made. But in doing so they find $1 \cdot 32$ as the value of ν, in place of $1 \cdot 40$ as I find from calculation. The cause of the difference is clear. To measure the maximum of total induction they wrapped a

secondary wire round the middle of one of the limbs. This wire was connected with a ballistic galvanometer. The deflection produced by short-circuiting the field-magnet coils gave a measure of the induction at the middle of the limb. If they had wrapped it round the yoke end of the limb, where the deflection would have been greater, the increased value would just have made up the difference between the Hopkinsons' observations and my calculations. Professor Forbes.

The Hopkinsons' curve does not fit in with the observations at the higher values of the induction. They suppose this to be due to the fact that the value of ν is variable. Their error is only due to taking $\nu = 1{\cdot}32$ instead of the higher value $1{\cdot}40$.

During the last eight or nine months I have been testing constantly the designs of dynamos and motors, and the experience I have gained in calculating the magnetic resistance of air spaces has so trained my judgment that I feel great confidence in calculating ν in any type of dynamo. Any one can gain this confidence by practice.

It has long been a puzzle to me to know why so much power and copper are wasted by dynamo makers in their field magnets. I want to know why they wind wire round the field magnets instead of round the armature. When I design a dynamo I want to magnetize the armature rather than the field magnets, since the result obtained is proportional to the magnetization of the

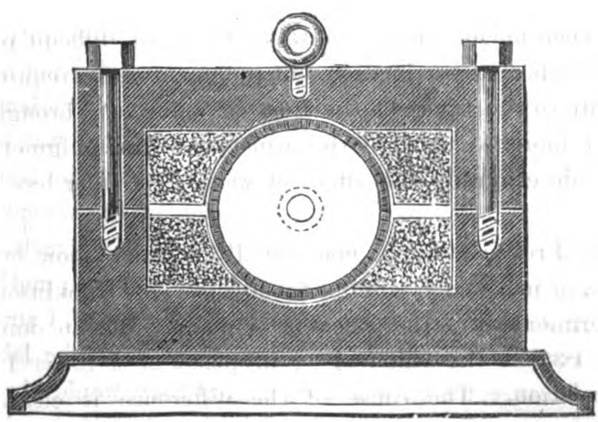


FIG. 6.

Professor Forbes.

armature, not of the field magnets. If I wished to make the Crompton dynamo really efficient in working and economical of construction, I would build it as shown in the diagram. The wire is wound round the armature. The pole-pieces should be more extended than shown in the figure. About one half the copper now used will be required. There will be less weight of iron. The waste lines of induction will increase the induction through the armature instead of diminishing it. Thus, if I reduce the number of ampère turns in the ratio of $2\,\nu : 1$, which is probably about 2·8 to 1, I obtain the same effects as with the machine in its present form.

Dr. Hopkinson.

Dr. J. HOPKINSON: Mr. Kapp, and Professor Forbes, introduce into the consideration of magnetism the analogy of the resistance of electrical conductors. Now that analogy does hold to a certain extent, but not completely. With electrical conductors we have the exceedingly simple law, that the current in any conductor is directly proportional to the difference of potential between its ends. Unfortunately, that law does not hold in the case of magnetisation of iron. The induction in the iron is a very complicated function, and the better plan is not to trouble oneself about any supposed analogy between that function and electrical resistance.

The question of the waste field is dealt with in Mr. Kapp's paper. The waste field of a dynamo, if I understand him rightly, is not made the subject of any independent determination; it is a flexible element and can be fitted to the actual observation. In the case of my brother's work and my own we did not attempt to calculate it, but we made it the subject of a determination by a wholly independent method, when the machine was at rest, with the aid of a galvanometer, and owing to that the results we obtained are really a complete verification of the already well-known magnetic theory which is applied to the treatment of dynamos. We did not apply, and did not attempt, methods of calculation such as Professor Forbes has made use of, I am afraid, we must confess, because we perceived they would be laborious, and also because we were not clear that they would throw any fresh light upon the subject. I think Professor Forbes is to be

congratulated very much in the success with which he has worked out this method in the cases to which he has applied it. It may be worth while to mention that the method which Professor Forbes used, and which we also use for the particular purpose of showing the amount of the extension of the field was not anything extraordinary or more than one would naturally expect, is really a method due to Lord Rayleigh who, in his book on "Sound," deals with the question of the extension of the length of an organ pipe owing to its open end, and points out that the same method is equally applicable to the case of electrical conductors. Imagine a wire soldered into a solid block of metal, coming out from it perpendicularly. We all know that the resistance of the wire will be something greater than that due to the length as measured from the metal in which it is soldered. Lord Rayleigh showed that if you dictate the course which the current shall go through the wire into the mass of metal, and, having done so, you calculate what the extra resistance in the block will be, the actual resistance will be less than the resistance so calculated. That is really the method which Professor Forbes and ourselves have adopted. But Lord Rayleigh goes further and points out that you can get an inferior limit of resistance by supposing perfectly conducting surfaces approximately perpendicular to the lines of flow of the current, and then calculating what the resistance will be; and he shows that the actual resistance will be something more than the resistance so calculated. Two approximations are made by guess-work, and the truth lies between them. Dr. Hopkinson.

The fact that a considerable extension of the magnetic field must be allowed for in calculations of the characteristic of a dynamo was apparent to me some three years ago, when I was applying theory to the old Edison machine and to my improvements of it. I then used a method of calculation substantially similar to those now used, but only partially developed. I found that with those machines in the early part of the curve a greater potential was obtained from the machine than was calculated if one neglected that extension of the field. Though we did not attempt to calculate the value of the

Dr. Hopkinson. extension of the field in the Royal Society experiments, but took it from the actual observation of the machine when running, yet from the experiments on the first machine we do get a constant. We get this, that the extension of the field may be regarded as a fringe all round its perimeter, and equal in width to four-fifths of the distance from iron to iron, and, without further experiment, we employed that constant in a second machine we tried. We have then a constant, arbitrarily determined, but one which is now available for use by anyone, and which is I believe approximately correct.

Professor FORBES: In the Manchester machine the curve is obtained by that rule?

Dr. J. HOPKINSON: Yes, by that empirical rule determined by the observations on the first machine. Mr. Kapp gives some figures of magnetisation, and, with one exception, they are the highest magnetisations which I have heard of. Mr. Zipernowski told me that he had observed as much as 30,000 per square centimètre. It is not for me to doubt the accuracy of such results, but still I confess that I view them with some degree of astonishment. In the case of Mr. Kapp, we have an induction of something like 24,000 per square centimètre in C.G.S. units. The highest figure which has ever been under my own observations is that deduced from the experiments in the Manchester dynamo, which go up to 20,000. In laboratory work of my own the highest figure I ever obtained was 19,800, and that was in the case of the very best material I could get hold of—it was a rod of Whitworth compressed steel made of Swedish iron, and containing a very small percentage of carbon. It is most desirable that experiments should be made on the maximum induction, which can be obtained in soft iron with very much higher magnetising forces than have hitherto been employed.

Another point of great interest in connection with magnetisation, which is very desirable to follow up, is in connection with manganese steel. Steel with about 8 to 12 per cent. of manganese in it is sensibly non-magnetic, with magnetising forces up to 240 per centimètre, but it is not safe to assume that if we applied a large enough force to it we should not get its coercive force to

give way. It is a matter of great curiosity to me as to whether or not manganese steel can be magnetised by a sufficiently powerful force. Dr. Hopkinson.

Now as to one or two points in the discussion. Mr. Alexander Siemens very justly pointed out the desirability of aiming at durability in dynamo machines. It appears to me that he is entirely right; it is a most necessary thing. Well, surely the right way to secure it is to insist that dynamo machines should be severely tested; that if a dynamo is put down for a certain output of current, it should be run with that current for a very long time; not only that, but it should be run with a greater current to see that it is mechanically strong; it should be run at a higher speed and higher potential to test its insulation, and so on. I believe that durability is best attained by high efficiency. A machine with a high efficiency will, other things being equal, be a durable machine, it will have less sparking at the commutator, and it will be better in every way. Mr. Swinburne, on the other hand, urges that the great thing for dynamo makers to consider is cheapness of production. There again, I do not think any of us will differ from him, *cæteris paribus*, a cheap machine is better than a dear one; on the other hand, I suppose Mr. Swinburne will not deny that there is a point where cheapness may be purchased by too great a sacrifice of efficiency. Then it comes to be a question of economical comparison between cheapness and efficiency, and that is not a very difficult matter. Consider the question of two machines, one of which will give the same effect with a horse-power less than the other. If you take the dearer machine you save a horse-power so long as that machine is used. What is that worth? That depends on various things, the size of the engine, the place in which it can be put, whether gas or coal is used, and so on; but, speaking generally, and barring water-power, I think we may take it that a horse-power is very seldom produced at less than £5 per annum, and it very often runs up as high as £20. Well, as we cannot take a particular case, and must deal with it generally, let us suppose £10 per annum as a fair price for a horse-power. Now what is a fair outlay to save £10 per annum?

Dr. Hopkinson. There again there will be a good deal of difference of opinion, but we are making our allowances liberally, and will set down 10 per cent. for depreciation, and 5 per cent. for interest on the outlay which has to be provided to attain that saving, that gives £67. It is, therefore, worth while to pay £67, if thereby you secure a machine which consumes one horse-power less than another to do the same work. Put it in a concrete case. Take the case of a dynamo machine to give you an output of 50 electrical horse-power. One machine will do it with an expenditure of 55 and another with 56, a difference of one horse-power, or 2 per cent. It is worth while paying £67 for the more economical machine for the purpose of saving that one horse-power. At the same time it is very necessary that in making any such comparison you should be quite sure that you get what you are expecting to get, and you must look well into the evidence of the efficiency of the particular machines. Really the case might be put higher than I have put it, because the depreciation on the more costly and more economical machine will be less than on the cheaper and less economical machine.

In Mr. Crompton's remarks last time great stress was laid upon what could be done by an eye. I quite agree with him. Mr. Crompton has a good eye, and it is a very valuable possession to him. I quite agree with him that a good eye is worth a great deal. It seems to me something like this, that a man with an eye, and a hand, could do some pretty efficient fighting without a weapon, but a man with neither an eye nor a hand, and only a big gun, would not do very much efficient fighting; but with a big gun and with hand and eye together he would do the best fighting of all. So it is the case with dynamos. What is wanted is not to depend upon mathematics alone, but to have a general appreciation whether the thing looks about right, otherwise mistakes will be made however perfect the mathematics may be. I think it was Sir Wm. Siemens who once said that mathematics was an "exceedingly good servant, but a very bad master." That is perfectly true, but there is a corollary—that the best way of avoiding being mastered by your servant is to be master of your servant, and consequently

I do not think that that remark at all depreciates the value of the use of mathematics in its proper place and in its proper way. As to the use of graphical methods in studies of this kind: there again I think that both the graphical and algebraic methods have their proper place. There is a great advantage in using graphical methods over using algebraic methods in some cases. If you make use of an empirical formula to express a physical law, you get a nice simple formula and it becomes your master, and you cannot believe anything that goes contrary to it; it seems to me, therefore, that a graphical method is always better than a purely empirical formula. At Cambridge, the rule is in a part of the mathematical tripos that you are only to use geometrical methods. But candidates soon learn that they can get round that rule by working out the problems by powerful analytical methods, and then translating to geometrical methods. So it is here that, instead of being under any hard and fast rule, we can do as we like and get the advantage of a combination of analytical with graphical methods. But I do feel very strongly that the use of empirical formulæ, such for example as that introduced by Frölich for the characteristic curve of a dynamo, is full of danger. One presently begins to think that the empirical formula, which is only intended to be used as an expression of the results which have been obtained by experiment, is really a law of nature. Dr. Hopkinson.

Before I sit down I cannot refrain from saying that I do compliment Mr. Kapp most heartily upon the paper which he has read to the Society. It is clear that Mr. Kapp has worked out what he has placed before the Society by his own efforts, and that he has done so with very considerable success.

Dr. J. A. FLEMING: I should like to make a few remarks on some figures I have in my hand, derived from experiments by Mr. Shelford Bidwell, on the magnetisation of iron rings. Mr. Bidwell has obtained the magnetisation and susceptibility of iron up to very high magnetising forces in the case of iron rings. If we take the well-known form of Frölich's formula, Dr. Fleming.

$$M = \frac{H}{a + 6\ H},$$

Dr. Fleming. when M = magnetisation, and H = magnetising force, and write it

$$a + 6\,H = \frac{H}{M},$$

we see that the right-hand side of the equation expresses the ratio of magnetising force to magnetisation. This, in the case of the ring-magnet experiments, is simply the *susceptibility*, and accordingly the above formula is only a statement of the fact that the reciprocal of the magnetic susceptibility is a linear function of the magnetising force. Now, when Mr. Bidwell's figures are plotted out, it appears that the results give a very fairly straight line as the graphic expression of the relation of these two quantities, when the magnetising force extends over a range of from 10 to 600 C.G.S. units. The reciprocal curve is a hyperbola; and we should therefore expect to find that if susceptibility is expressed as a function of magnetising force, its graphic representation will be a hyperbolic curve. Stoletow has given this curve, and it appears from examination of his curve that it is sensibly hyperbolic above values of H, equal to about 10 C.G.S. We may take it therefore that Frölich's formula is an algebraic expression of this fact, and that is confirmed by observation. It is needless to point out that there is no physical basis for the expression. After what Dr. Hopkinson has shown us in his paper, it is evident that his graphic method affords a better and more scientific method for the predetermination of the characteristic curves than the use of an empirical formula. Whilst sharing with others admiration at the useful and suggestive paper of Mr. Kapp, it is gratifying to observe that even if England falls behind other countries in practical extension of electric lighting, English engineers and physiasts are leading the way to a true theory of that most perfect engine, the dynamo-electric machine.

Mr. Walker. Mr. SYDNEY F. WALKER: I would like to make just a few observations on the practical side of the question. As a dynamo manufacturer I can cordially endorse all that has been said as to the great value of Mr. Kapp's work. I do not think I am exaggerating when I say that previously to his work, to the

announcement of the law, however imperfect it may be from an accurately scientific point of view, the dynamo machine was the master of the manufacturer, now the manufacturer is the master of the machine, and that is, I think, a very great point. The firm with which I am connected have, since the expiration of the old Gramme patent, kept on the manufacture of the old Gramme machine upon the old lines, which I am pleased to see by Professor Forbes' work, is perhaps not such a bad design after all, for, as I gather, the magnetic leakage in that form would not be so great as in some of the more modern forms. Since Mr. Kapp announced his law, we have made use of the formula, and it has shown us how to adopt the modern improvements, how to alter the old machines and keep their simplicity (which I maintain is a very great feature in manufacturing); and it has not only done that, but it has also shown us how to obtain from the old iron carcase, simply by a reconstruction of the armature and a rewinding of the field magnets, a very greatly increased output. For instance, the old B, which I think used to give us about 3,000 watts, we have been able to get 10,000 watts from, which I think is a very great feature. In following out the formula of Mr. Kapp I have found it quite true, with this reservation, that after we had estimated all the resistance, which is perhaps not an easy matter in some of the old pattern machines where the sides were cut away to look pretty, and perhaps to save iron, but after we had estimated that as carefully as possible, we had to apply a constant—that is to say, to apply more exciting power than the formula would show; and I gather, from the scope of the paper, that this would be due to a very large extent to magnetic leakage. I think, if you explore the neighbourhood of any dynamo machine you will find strong traces of magnetism. I have found very strong traces of magnetism at very great distances from almost every type of machine, and, as in fact, all such lines of force are so much power put into the magnetising field which is simply wasted, which has, of course, to come originally out of your steam generator or gas generator, as the case may be. I notice, however, an apparent contradiction in Mr. Kapp's paper. I understand, unless I read the paper wrongly, Mr. Walker.

Mr. Walker.

that he states that, after you apply his formula for finding the electro-motive force, given a certain machine with a certain number of turns and with a certain speed, after estimating the magnetic resistance and applying a certain magnetising power, with a certain number of ampère turns, you get, not the electro-motive force which you should get, but a higher electro-motive force. I do not know if I have read that rightly, but it appears to me to be a contradiction, and I take it that given a certain magnetic resistance following the leading, say, into the armature and out of it again, and given a certain exciting power round your field magnets, you produce a certain number of lines in your field, and they do not all get into your armature, as Professor Forbes and Dr. Hopkinson have shown, but a percentage of them is wasted, and therefore it appears to me that the electro-motive force you should get should be lower than the formula would show; and that tallies, I think, with my own experience in the dynamos that have passed through my hands. Then with regard to the analogy which Mr. Kapp has introduced, of the leaky battery. It appears to me to be a very appropriate analogy, but he has hardly read the full lesson that it would teach us. If we have a leaky battery, or a leaky line, which almost amounts to the same thing, the first thing we do, of course, is to try to insulate it. But there are many cases, at any rate, where you cannot insulate; in my own practice, which is largely connected with collieries, we have hundreds of cases, I may say, where it would be merely waste of time to try and insulate—there is a leakage current and it cannot be helped. A leakage current may be dealt with in three ways, and I take it that that is a close analogy to what you have in a dynamo. You have a leakage, and you cannot help it by altering the construction of the machine; you will have the leakage to a certain extent. The first way to get over it is the plan followed by every telegraph-engineer in the early days of telegraphy, by increasing the battery power, which, I take it, corresponds to Mr. Kapp's plan of increasing the exciting power. That is a wrong plan, because, by increasing the electro-motive force you increase the leakage, and, of course, every cell added increases the trouble. The next,

and a better plan, is to increase the size of your cells, *i.e.*, you have a certain leakage current, and you want a certain working current, and you must provide for it by the increased size of your cells, so that the batteries will last, notwithstanding the leakage current, for a certain time; that corresponds, I take it, perhaps more nearly to Mr. Kapp's proposal to give an increased section of iron in the field-magnet cores over that in the armature. But I think that is hardly the most economical plan, because you have to remember that by increasing the size of your cells you are indirectly increasing the electro-motive force, driving the leakage current through, and therefore you are increasing the leakage current. The same in the dynamo; by increasing the section of the iron in order to keep the exciting power constant you are doing the same thing, you are increasing the magnetic potential at the point where the leakage is greatest. A third plan that we adopted to get over the great difficulty that we had with colliery signals was to reduce the electro-motive force, and to reduce the resistance in proportion, and that, I think, is the lesson that we should learn from the analogy that the leaky battery has to dynamo machines. In making modifications of dynamos in the future, we should reduce the exciting power, and reduce the magnetic resistance of the machine all through, not only in the core and the field magnets, but reduce the resistance in every possible direction, so that the proportion between the resistance of the natural flow that we want through the armature core shall be very much greater to the leakage resistance where we do not want the lines to go, than it is now. That means, of course, that we should have less copper and more iron—there is a limit beyond which you cannot go in that direction. I do not quite understand Professor Forbes' suggested design of a dynamo, perhaps he will explain it to me afterwards, but apparently something in that direction would be the natural outcome. I take it that the magnetic resistance there is reduced to a minimum. But apart from that design, the direction in which we should go is to put more and more iron and less and less copper, and the limit at which we must stop, I think, is measured by a very simple formula. It is limited when the interest

Mr. Walker.

Mr. Walker.

upon the amount represented by the increase of iron, plus the increased cost of handling and machining that iron, is equal to the interest upon the amount represented by the wire saved and the cost of winding it; and to that interest you have to add the interest of the horse-power saved by the leakage which is saved.

With regard to the lines in the armature, I do not know whether I have made my calculations wrong in armatures that have passed through my hands, but I have certainly many armatures running with 25 lines, according to Mr. Kapp's notation. I can certainly cordially endorse the remark of Mr. Siemens, that we should have a margin of safety. There is too great a temptation if, say, a machine is stated to give say 200 or 300 lights to see if it will not give 5 or 10 more, and possibly it will; but contractors, and users, and everybody knows that by doing so the machines are wearing out too quickly and it would be far better to pay another £50 or so and run the machine under power.

Professor Thompson.

Professor SILVANUS P. THOMPSON: I have not had the benefit of hearing the remarks of Professor Forbes or of Dr. Hopkinson in this debate, but I cannot help expressing my feeling that we are under an enormous debt to both Mr. Kapp and Dr. Hopkinson for the contributions which they have made to this subject. The calculations which they have made in their respective ways of the actual working magnetism of a magnetising circuit when excited by a given number of ampère turns is certainly most valuable. Both papers propose to arrive synthetically at the construction of the characteristic curves of dynamos. What both papers succeed in arriving at is the synthetic construction of the curves of magnetisation of dynamos. The curves of magnetisation are not, however, the same as the curves which for the last five years have been known to electrical engineers as "*characteristics*." This term, introduced in 1881 by M. Marcel Deprez, is used to denote a curve which represents the relation between the electro-motive force and the current of a machine. Such a curve was first constructed by Dr. J. Hopkinson in 1879 (see *Proc. Inst. Mech. Engineers*, April 25, 1879), who also, at the time, pointed out as

one of its most important and useful properties that it resembled an indicator diagram, inasmuch as the product of the ordinates and abscissæ were proportional to the work done in unit time. Engineers are now gladly adopting the use of the characteristic curve for this reason. The convenient name suggested by Marcel Deprez has been welcomed, and the properties of the characteristics of different kinds of machines observed. For example, the flatness or otherwise of the characteristic of a compound-wound machine affords information as to the perfection of its self-regulation. The inflexion of the characteristic of a magnetic machine, or of an independently-excited machine, affords a measure of the several reactions due to self and mutual induction, and other perturbing causes. The peculiar hyperbolic characteristic of shunt machines presents several noteworthy points. In all dynamo machines the difference between the total characteristic and the external characteristic (that is to say, the curves drawn with volts and ampères measured on the one hand for the whole output of the machine, on the other hand for that part of its output which is available in the external circuit), affords most useful information as to the electrical efficiency of the machines at all stages of their work. Professor Thompson.

Now the curves which Mr. Kapp and Drs. J. and E. Hopkinson have been building up are not characteristics at all in this sense. They are not diagrams in which the products of abscissæ and ordinates represent *watts*. They are merely curves of magnetisation, characteristic, if you like, of the magnetism of the machine as developed by exciting the field magnets by a current. I should prefer to call them saturation curves, as exhibiting the facts of magnetic saturation (and leakage) in relation to the magnetic excitation of the current. It is true that the curve that is characteristic of the magnetisation is, in series-wound machines, very much like the characteristic of the machine; though even here, as I have carefully pointed out in my treatise on the subject, there are differences which cannot be overlooked.

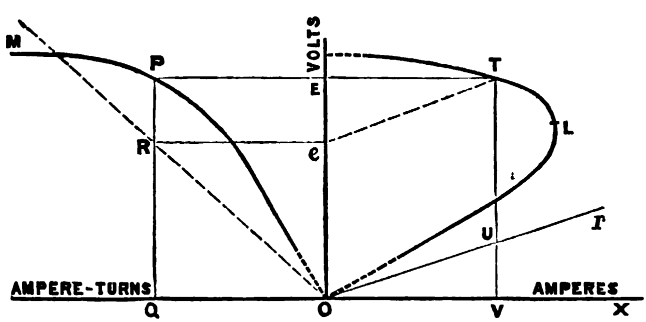
But the characteristic of the shunt machine is essentially different from that of the series machine. In the series machine the volts are small when the ampères are small, but as the

Professor Thompson.

ampères increase the volts increase—the total volts increasing as towards a limit, the external volts increasing at first and then diminishing, so that the external characteristic rises from the origin, ascends to a maximum, then descends again. In the shunt machine the characteristic begins at its highest point, and thence falls, the ampères increasing up to a certain limit, and then diminishing again, the curve bending inward towards the origin. This is entirely unlike the curve of magnetisation; though, as I shall show, it is easy to calculate the one from the other.

Now, if I am rightly informed, not one of the machines referred to by Mr. Kapp in his paper was a series-wound machine; and, I believe, the same remark is true of the two machines described by Drs. J. and E. Hopkinson. We have yet to await the synthesis of their characteristics.

It is easy (assuming absence of reactions due to armature) to obtain the characteristic of a shunt-wound machine from the curve that is characteristic of its effective magnetism.



First draw, reversed to the left for convenience, the curve of effective magnetism, plotting out the ampère-turns of the shunt-excitation along O Q, with the corresponding values of effective magnetism as ordinates. The proper unit for the latter should be the number of C.G.S. lines of force multiplied by the speed (in revolutions per second) multiplied by the number of external conductors on the armature that are in series with one another from neutral point to neutral point, the product divided by 10^8 to reduce to volts. The curve, in whatever units the scale is

expressed, will be like O P M. Then set out at O an oblique line, O R, making, with O Q, an angle such that its tangent is equal to the (average) resistance per turn of the shunt coil. Then, if we consider any point P on this curve, the height of its ordinate, P Q, will express, according as we please, either the effective magnetism when the excitation is O Q, or the whole number of volts E induced in the armature rotating at the given speed; and the portion R Q of the ordinate will represent the difference of potential e at the brushes of the machine. For calling Z the number of shunt turns of wire, i_s the shunt current, and r_s the shunt resistance, we have— Professor Thompson.

$$\mathrm{O\,Q} = Z\, i_s,$$
$$\tan \mathrm{Q\,O\,R} = \mathrm{R\,Q} \div \mathrm{O\,Q} = r_s \div Z,$$
$$\text{whence } \mathrm{R\,Q} = Z\, i_s \times r_s \div Z = i_s\, r_s = e.$$

That is to say, the intercepts of the ordinates between the curve OPM and the line OR represent the values of E—e; that is to say of the volts which are unavailable for external purposes, but which are required to drive the armature current through the armature's own resistance. But these last volts E—e are proportional to the armature current. Therefore, draw from O another sloping line, O r, at such an angle that tan X O r is numerically equal to the internal resistance of the armature. Project P and R across horizontally through E and e on the vertical axis (axis of volts), and from e draw eT parallel to O r until it cuts P E produced in T. T will be a point on the (total) characteristic of the dynamo; for, dropping the perpendicular T U V, the intercept U V is equal to P R, hence O V is the number of ampères which, flowing through the resistance represented by the slope of O R, will correspond to U V volts. The co-ordinates of T therefore represent the values of total current and total E. M. F. given by the dynamo at that stage of magnetisation. Other points may be found similarly, and will give a curve such as O L T, which will at once be recognized as the usual characteristic of a shunt dynamo.

It is possible in the same way to build up from the curve that is characteristic of the effective magnetism the characteristic

Professor Thompson.

curves of machines having compound windings, whether self-regulating or not.

I must protest strongly against the hybrid units in which Mr. Kapp indulges. The C.G.S. system of units may be very puzzling to those who cannot work decimal sums, and who prefer halves, quarters, eighths, and sixteenths of an inch. But, admitting the C.G.S. system, and the ordinary units of electric measurement that are founded upon it, it is really most deplorable to find the C.G.S. units of magnetic force mixed up with the square inch as a unit of area and a minute as the unit of time. The simple result is that Mr. Kapp's figures, for the strength of his various fields and amounts of magnetic induction, convey no meaning whatever until they are reduced to C.G.S. units, so as to compare them with what other experimenters have obtained. According to my reckoning, the new Kapp magnetic line of force is equal to 6,000 lines of the C.G.S. system, and his one (Kapp) line per square inch is equal to about 930 (C.G.S.) lines per centimetre. Hence his highest value for the magnetic induction in armature cores is about 23,250 C.G.S. lines per square centimetre, or 232·5 microgausses. I would suggest to Mr. Kapp that, when his paper is printed, he should give the various values, reduced to the corresponding C.G.S. units, in parallel columns.

With respect to the so-called Frölich's formula, for expressing the relation between the effective magnetism and the exciting current, I maintain that it is, though admittedly only a first approximation, a sufficiently near one for practical purposes; and, according to Dr. Frölich's experience, it fits the facts better than the old arc-tangent formula of Müller, which is now revived by Mr. Kapp. The main objection to the arc-tangent formula is its extreme inadaptability for use in the further equations of dynamos, whereas the hyperbolic expression known as Frölich's is extremely apt for that purpose. I do not know whether Mr. Kapp is aware of the recent simplification which Dr. Frölich has introduced into the formula, rendering it still more readily applicable in the calculation of all kinds of quantities, such as occur in dynamos. I have myself shown some of its useful

applications in the elementary theory of various types of machines. Professor Thompson.

As to Mr. Kapp's attempt to justify the arc-tangent formula, on the ground that the particles of iron in a field-magnet core might happen to act like a lot of little tangent-galvanometer needles, I am bound to say I fail to see the cogency of the argument; for galvanometer needles, whether long or short, do *not* follow the tangent law unless they are restrained by a constant force acting at a right angle to the line of the magnetic force. Is Mr. Kapp prepared to hold that the forces resisting magnetisation in an iron bar are all transverse forces of constant amount? If so, what proof can he offer of the matter?

Lastly, Mr. Kapp, though he gives us, to compare with the actual curve of magnetisation of a Phœnix dynamo, a curve which he states is calculated from Frölich's formula (intersecting in a certain assumed point, and that not the right one if the method of least squares had been adopted), has not given the corresponding curve for the arc-tangent formula intersecting at the same point. Had he done so it would have been at once apparent that even then there is practically no advantage in the arc-tangent formula, as it also only approximates to the observed curve, which, from its concavity near the origin, appears to have been taken with ascending magnetic forces, not with descending. For shunt machines the descending curve is much more nearly true to the state of things in practice; for in practice shunt dynamos are usually started with larger external resistances than are afterwards used during running.

I would just remark that I have been struck with the enormous waste of magnetism in the Edison form of machine by leakage through the bed-plate. In a machine of the old Edison form which we have at Finsbury I am afraid to say what the percentage of leakage is from that cause, but I should not be at all astonished to find it 30 or 40 per cent. In Dr. Hopkinson's paper on the latest form of the Edison-Hopkinson machine that leakage was stated, I believe, to be something like 10 per cent.

Dr. Hopkinson: Yes, something like that.

Professor S. P. Thompson: Twenty-four per cent. altogether, 10 through the bed-plate.

Professor Thompson.

Dr. HOPKINSON: Yes.

Professor S. P. THOMPSON: I would suggest that instead of zinc in the bed-plate manganese steel should be employed, on account of its lower magnetic properties and superior strength. A much higher footstep could be made without injuring the machine or its mechanical properties.

The President.

The PRESIDENT: Evidently at this late hour it would be very unfair to call upon Mr. Kapp to reply, and in fact it was foreseen by the Council that this discussion would be a most interesting one, as it has proved, and would probably not finish to-night; and as there are many papers before us it has been decided to call an extra meeting for next Thursday, when, after Mr. Kapp has replied, the paper by Mr. Swinburne set down for this evening will be read.

A ballot took place at which the following candidates were elected:—

Associates.

Frank A. Bailey.
Alfred E. Braddell.
Francis J. E. Clarke.
James Fraser.
John Gilbert.
Ludwig L. Hartvigson.
William Thomas Hoal.
John E. W. Imrie.
Arthur Maitland Keays.
William Perren Maycock.
E. Celso Mozzoni.
Frederick Ernest Oldham.
The Count Stanislas Julian Ostrorog.
Ernest Payne.
William Morse Robinson, jun.
Arthur Whitwell.

Students.

Burton Brown.
Albert L. Davis.
Bernard Maxwell Jenkin.
Hubert Olliver.

The meeting then adjourned.

An Extraordinary General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, December 2nd, 1886—Professor D. E. HUGHES, F.R.S., President, in the chair.

The minutes of the previous meeting were read and approved.

The PRESIDENT invited further discussion on Mr. Kapp's paper, which was adjourned from the last meeting.

Professor PERRY: At this period of the discussion I feel that it is one's duty to cut one's remarks very short indeed. At the last meeting I came prepared to say something if called upon, but I am now glad to think that most of my remarks have been anticipated by other speakers. I think, however, that it is my duty, even now, to point out that this paper of Mr. Kapp's is really, in quite an exceptional manner, a very useful one, for by the method described in it we can calculate the characteristic of a dynamo in a most straightforward way from the beginning to the end without difficulty, so that even the youngest member of the Society, in dealing with dynamos, can make the calculation. Mr. Kapp has with great clearness put forward his whole method, and the principles underlying it. In a manufacturer, such a course of action is exceptional, and he has well earned our gratitude. Others may have anticipated him, using a method somewhat similar to his, but Mr. Kapp was the first to make this valuable practical method of calculation public property. Now, in Mr. Kapp's calculation, the most important matter is the determination of the leakage resistance; the whole method is based on the assumption that the leakage resistance is known. I take it that in his method he guesses at the leakage resistance, and he applies his guess in his calculation until it fits the characteristic of a particular dynamo machine. Dr. Hopkinson takes a somewhat different method: he has, after constructing a dynamo machine, by putting coils in certain places, measured the leakage, but not the leakage resistance, and from that leakage he makes his calculation. Now I think there is a little weakness in both Professor Perry.

Professor Perry.

methods, for unless the leakage resistance of a dynamo can be calculated from the drawings, before the machine is actually made, we cannot predetermine the characteristic of the dynamo. I was glad to hear Professor Forbes dwell upon this point at our last meeting, for it is evidently of supreme importance to predetermine what may be called the leakage resistance. Dr. Hopkinson may be said to differ from Mr. Kapp, because he does not speak of a leakage resistance, but of a leakage; and, for reasons which I will give you presently, I think Dr. Hopkinson in the wrong, and that Mr. Kapp is quite right in using the idea of a leakage resistance.

I am sorry to say that I cannot approve of Professor Forbes' calculation. His object is so important that I feel compelled to put my objections on record. He remarked that he did not have to use his judgment very much in making the calculation. Now it strikes me that he did use his judgment very much indeed. This calculation of the leakage from one part of the electro-magnet to another is very difficult, and it seemed to me that Professor Forbes was, all through, using his judgment as to whether he would or would not take his leakage as occurring between certain places and certain other places. Again, he chose the shape of his leakage lines, the lines of flow of the magnetic induction. Again, he chose to confine them to certain small spaces, these lines which roam freely through infinite space. Again, in considering the leakage from limb to limb of the field magnet, he certainly made a possibly correct guess at the nature of the leakage at one or two places, but he left out a most important matter, the leakage from the flat sides of the limbs which are remote from one another and yet the limbs are wide apart. Again, we know that points in each limb differ in potential; he took the mean potential in each limb as a potential common to all points in that limb, but I am prepared to show that his answer for this important item is half as much again as it ought to be.

[Professor Forbes here remarked that his calculation had been misunderstood.]

I do not think that I have failed to understand Professor

Forbes on this point, but even if I have, the other matters which I have mentioned are grave enough to furnish an indictment. It seemed to me that he was depending altogether on his judgment as to what happened and how the leakage got from place to place. What strikes one with astonishment is not the beauty of the method adopted by Professor Forbes, but his exceeding good fortune in having obtained an answer which agreed with Dr. Hopkinson's experimental result. Dr. Hopkinson objected somewhat to what is called the electric analogy, and, as you have listened to the proceedings during the last two meetings, I suppose that everybody who hears me is aware of what I mean by the electric analogy, first put forward by Faraday. Now, I take it that Dr. Hopkinson's objection was really not to the analogy in its essence, but to the misleading way in which it may be taken up on account of a change of the magnetic resistance of the iron, which there is almost no analogy for in the case of currents. Professor Ayrton and I have gone pretty carefully into the question of this leakage from one limb of the magnet to another. Suppose a yoke with no resistance, and we consider the leakage from one limb to another limb of a field magnet—of course leakage will occur in a great number of places, through all space in fact; but if we think of the leakage resistance in Mr. Kapp's way, and if the leakage resistance is greater than four times the resistance of the armature, and also of the resistance of the limbs of the electro-magnet, it will be found that we may regard the leakage resistance as a constant in all calculations however the other resistances may alter. That is, within certain limits, the leakage resistance may be regarded as a constant up to four-fifths of what we are in the habit of calling saturation. That is, up to four-fifths of saturation of the iron, Mr. Kapp is right in his way of putting the electric analogy. I have no time to indicate the nature of the proof of this very important theorem, but I have drawn attention to it because Dr. Hopkinson differs so materially from Mr. Kapp in this very important matter. Professor Perry.

Time is getting on and perhaps the discussion should close, but I should like to say a few words about the use of empirical formulæ. I believe that empirical formulæ are of tremendous

Professor Perry. use to people who are taking up some of the many investigations connected with dynamo machines. Nearly all the laws that I know of in connection with dynamos, compounding and so on, have been worked out algebraically, by simple algebraic formulæ, by empirical formulæ which were known to be very wrong indeed. Rules are worked out algebraically, and when we have obtained the rules it is easy to find a graphical method of employing these rules. The ordinary graphical methods which we know of were really discovered algebraically, and when Dr. Hopkinson gives the advice to young engineers to use only graphical methods I think he is giving advice that is a little misleading, and that he does not quite understand his own and their relative positions. When a senior wrangler uses a geometrical method he uses along with it, instinctively, unconsciously, a number of other mathematical methods of working; but an ordinary practical electrical engineer will find far more advantage in using an empirical formula, even though that empirical formula is slightly wrong, than in using the graphical method. I should advise the use of that formula which is called Frölich's, but which Professor Ayrton and I worked out some three years before Frölich said anything about it. Rücker and Frölich have shown that formula to be exceedingly useful in dynamo calculations. It needs only the predetermination of one constant, and not two, as Mr. Kapp has said, for any particular machine, and I should advise that constant being determined by making Mr. Kapp's calculation for a value of z about two-thirds of saturation, and letting the formula fit that one point of the true characteristic. If anybody expects to get very much more exactness than the formula will give him in the predetermination of a dynamo, I think that he will be disappointed.

I would just say a word about something that occurred, I think in 1880, which Mr. Shoolbred's presence here reminds me of. At that time Mr. Shoolbred showed the characteristic of a dynamo at a scientific meeting, and that characteristic showed a drop of the curve towards the end.

Mr. Shoolbred. Mr. J. N. Shoolbred regretted that he had not had opportunites latterly of following, with sufficient closeness, the question

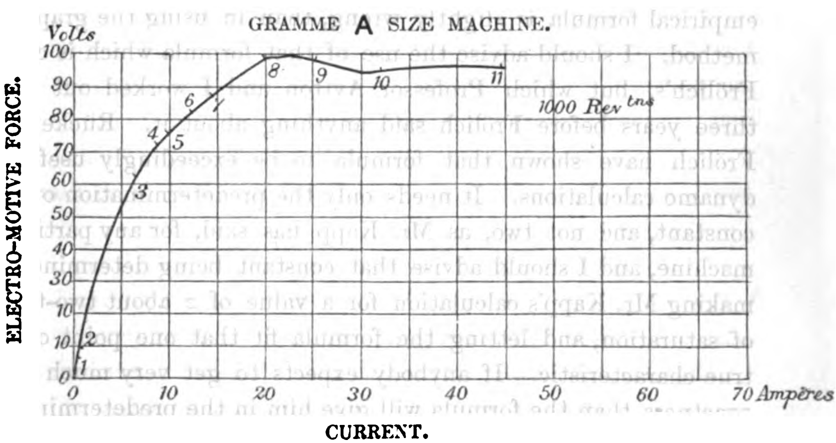
of the characteristic curves of dynamo machines, to enable him to discuss Mr Kapp's able paper on the subject. Mr. Shoolbred.

As Professor Perry had, however, referred to a form of characteristic curve which had been shown by him (Mr. Shoolbred) at a meeting of the Institution of Mechanical Engineers as far back as April, 1880, it might be of interest to refer to that curve, especially as it had been the subject of some comment and discussion at the time.

Dr. Hopkinson had exhibited characteristic curves which were the result of experiments on Siemens' machines and on a Gramme machine—curves all of extreme regularity.

[The speaker exhibited the curve, shown below, from an A size Gramme machine, taken from experiments made at Silvertown by the India-rubber and Gutta-percha Company, and kindly furnished for the purpose to Mr. Shoolbred].

The peculiar deflection of the curve, between the 8th and the 11th points of observation, was naturally the subject of much



(See Proceedings Inst. M.E., 1880.)

comment. Especially as the curve shown by Dr. Hopkinson from a Gramme machine showed no such deflection. That curve, however, did not extend further than about Observation No. 8 in the curve here shown.

It was urged that, had Dr. Hopkinson's Gramme curve been continued as far as the Silvertown one, a similar deflection would have been remarked.

ɔolbred. Dr. Hopkinson "thought, that the inflection at the top of the curve must be due to some uncorrected error of observation."

A subsequent and careful repetition of the experiments only confirmed the original curve.

Dr. Hopkinson, however, continued his investigations on the subject of Characteristic Curves.

In 1883, in his lecture before the Institution of Civil Engineers "On Some Points in Electric Lighting" (one of the series, "On the Practical Applications of Electricity"), he said, "While I am speaking of characteristic curves there is one point I will just take the opportunity of mentioning. Three years ago Mr. Shoolbred exhibited the characteristic curve of a Gramme machine, in which, after the current attained to a certain amount, the electro-motive force began to fall. I then said that I thought there must be some mistake in the experiment. However, subsequent experiments have verified the fact; and, when one considers it, it is not very difficult to see the explanation. It lies in this: after the current attains to a certain amount the iron in the machines becomes magnetically nearly saturated, and consequently an increase in the current does not produce a corresponding increase in the magnetic field."

"The reaction, however, between the different sections of the wire goes on increasing indefinitely, and its effect is to diminish the electro-motive force."

In his recent paper "On Dynamo-electric Machinery" (read before the Royal Society, May, 1886), Dr. Hopkinson further confirms, at p. 346, the theory of his views as above expressed.

He does not, however, consider that in modern machines the point is ever reached, where the deflection commences.

e esident. The PRESIDENT: I must confess that this paper has deservedly led to a most interesting and valuable discussion. I do not know which to admire the most, the paper itself, the discussion, or the reply; they are all admirable in their way. I think the time has arrived when we must call upon Mr. Kapp to give us his reply.

. Kapp. Mr. GISBERT KAPP: Before I answer some of the questions in detail, I should like to refer to a point in the paper which I am afraid has not been understood in the sense I meant it. Severa

of the speakers seem to be under the impression that I deny the existence of leakage in weak magnetic fields. This was not my intention. The paper says that "for the early stages of magnetisation leakage has very little influence on the exciting power; in other words, that the creation of leakage or waste field does not materially increase the expenditure of energy required to produce the useful field," and by referring to the diagram (Fig. 1) you will easily see what is meant by this remark. To fix ideas, let us substitute for the leakage going on all around the battery an artificial leakage taking place through a wire of a comparatively high resistance. The working current in R a will evidently not be sensibly diminished, whether we join the poles of the battery by such a high resistance or not. Anybody who has had to do with secondary batteries knows that the addition of, say, one single glow-lamp across the terminals of the battery does not lower the current flowing through the rest of the lamps. But if the battery has a comparatively high internal resistance (which in the magnetic analogue would correspond to the magnetic resistances of the field magnets when near saturation) every additional parallel circuit will produce a sensible diminution in the current flowing in the other circuits, or, if the latter must be kept constant, will require a considerable increase of electro-motive force. In the magnetic circuit of a dynamo machine the presence of leakage requires a considerable increase of exciting power when the magnets are excited nearly to saturation, but not at the initial stages of magnetisation. In other words, leakage is of little importance at the earlier stages and of great importance at the later stages of magnetisation. Mr. Kapp.

I am glad that Professor Ayrton made his experiments with a horse-shoe magnet, having cubes for its poles so arranged as to take one, two, or three armatures, because in so doing he has verified the correctness of what he calls the law of parallel resistance. This law, in my first paper, was not explicitly stated, although it is implicitly given in the formula

$$Z = \frac{P}{R_a + R_a + R_f},$$

where the three resistances are in series, but where at the same

Mr. Kapp. time one of the resistances, namely, that of the armature, is composed of two parallel branches in the shape of the two semicircles forming the core of the Gramme ring. These two semicircles correspond to two of Professor Ayrton's parallel armatures. There is another point in those experiments which is of practical importance, namely, the fact that the flow of lines is not weakened if it takes place in two planes at right angles. At first sight this is a surprising result, but a little consideration will show that it cannot be otherwise, for the flow of lines in all disc machines takes place in two planes, and if this circumstance were a source of loss machines of the "Victoria" or the "Gülcher" pattern would never work as well as they actually do.

Mr. Swinburne and Mr. Esson referred to the question of relative area of core in magnets and armatures, but their figures are, I am afraid, obsolete. The sectional area of the magnet in an Edison machine is not equal to that of its armature, but sensibly greater. In the example of the machine described in Dr. Hopkinson's paper, the difference is 27 per cent.; but since the space inside the armature is of no value for winding, and since the cutting out of the core would not result in economy, this is hardly a fair test as regards the proportion. A better test would be a machine where the internal space is of value, such, for instance, as the "Manchester" dynamo, the armature of which is wound on the Gramme system. In this case we indeed find a larger proportion, namely, 1 to 1·65, for the machine described in the paper already mentioned. In the Goolden and Trotter machine the proportion is also considerable, being 1 to 1·40 instead of 1 to 1, as mentioned by Mr. Esson. In my own machines I allow about 50 per cent. more area in the magnet as compared to the armature, but this proportion must of course vary with the particular characteristic desired and with the point on the curve at which the machine is usually required to work. Mr. Esson told us that he found it advantageous to either increase the section of iron in the armature or reduce that of the field magnet, and asked how far he could go in this direction. I think that his present proportion of three to four is very near the limit of economical construction. If he overstep this limit he will

find that the leakage from the field magnet becomes so great as to practically prevent him from saturating the armature core. Mr. Fricker objected to my expressing exciting power in ampère turns, and suggested that ampère feet would be a more natural unit to employ. I would point out that practically it comes to the same thing whether we reckon in ampère turns or in ampère feet, inasmuch as the former term includes the latter. This can easily be seen from the following consideration. We know that the induction in the centre of a circular current C of radius r is given by the formula $\frac{2\pi C}{r}$, and, although the determination of the total number of lines which flow through the circle is a very difficult mathematical problem, we can take it that this number will be proportional to the induction at the centre multiplied by the total area. Since the induction at the centre is inversely proportional to the radius, and the area is directly proportional to the square of the radius, the product must be proportional to the radius and consequently also to the length of wire through which the current flows. From this consideration it will be seen that the number of lines passing through the coil is directly proportional to the length of wire; or, in other words, that every foot of wire is for a given current equivalent to so many lines. We arrive at the same conclusion by the use of my formula, for all the resistances in the denominator are in the form of a fraction, namely, length divided by area; and if we imagine two similar machines excited with the same number of ampère turns but of linear dimensions, varying, say, in the proportion of one to two, all the resistances in the larger machine will be only half of what they are in the smaller machine, and the ratio of exciting power and magnetic resistance, that is the number of lines will, in the larger machine, be twice what it is in the smaller machine. We see from this that the number of lines obtained, irrespective of the size of the machine, is, for a given current, directly proportional to the length of wire wound on the field magnets, and therefore Mr. Fricker's proposal to reckon exciting power by ampère feet is quite compatible with my formulæ, although I am afraid that by the introduction of this new term these formulæ would require considerable alterations. Mr. Kapp.

Mr. Kapp. Some encouraging things were said by Mr. Crompton for those who are not mathematicians, but at the same time he threw cold water over those who are not gifted with that peculiar "eye," and who have to toil along using such mental tools as algebra, trigonometry, and a very little calculus, in order to solve the problems which arise in the designing of dynamos. I hardly think it possible to make a sharp division between the man who works by the eye and the one who tries to bring his ideas into the concrete form of mathematical expressions. Both methods are useful, but as a rule they go hand in hand; ideas flow to and fro, and improvements are brought to light nobody knows exactly how. In this particular case the increase of iron in the armature was brought about partly by what I may call mechanical instinct and partly by a formula which I established, in the summer of 1882, for the purpose of determining the electro-motive force of Bürgin machines. It is the following:—

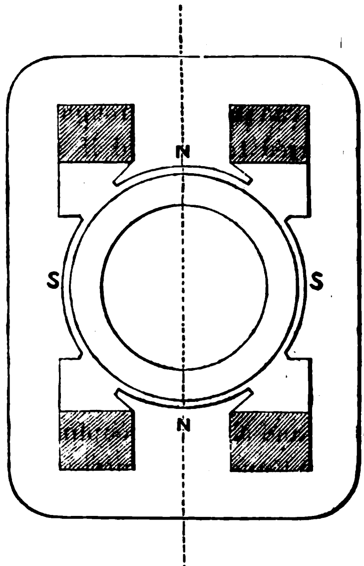
$$\Sigma_a = \mu \, a^{\frac{2}{3}} \, b \, \kappa,$$

in which μ was a co-efficient depending in some way upon the size of the field magnets. We found that by increasing these, μ could be increased; but when it reached the figure 38, or thereabouts, we found that further increase of iron in the field magnets would not produce a sensible increase of electro-motive force. It was then that we began to look to the other symbols, viz., a and b, in order to improve the dynamo. Since b (the length of the core) cannot be increased without lengthening the armature and making a more expensive machine, it was natural that our attention was mainly directed to the radial depth a, and as soon as Mr. Crompton recognised the fact that he could get more electro-motive force by a deeper armature core, he, with his usual impetuosity, jumped right to the other extreme, and made a dynamo which, I said at the time, had a ridiculous amount of iron in it. Although I was then opposed to a costly experiment so widely departing from the practice of the day, I am now very glad that Mr. Crompton has made such an experiment, for it showed at one step what could be done, and fixed a limit which might otherwise only have been

reached after a long series of experiments carried on step by step. Mr. Kapp. This machine, as Mr. Crompton said, converted me to the use of plenty of iron; but at the same time it converted Mr. Crompton a little in the opposite direction, and I think he would not at the present day make a machine which contains so little copper and so much iron, because it would be too costly for its output.

If it be permitted to the author of a paper to compliment a member who has taken part in the discussion, I would congratulate Professor Forbes on his very careful and painstaking way of working out the losses by leakage, and of obtaining figures so closely in accord with actual practice. The example chosen was, as Professor Forbes said himself, a very simple one, and I am afraid the calculation would in cases of greater complication be beyond the power of practical engineers; but it is important to see that the thing can be done with a fair degree of approximation. As a general rule, when making a preliminary estimate of the cost of a dynamo to give a stated output, I do not find it necessary to even employ my own simple formulæ for determining the leakage; I only estimate it by comparison with other dynamos which I have already tested, and leave the exact calculation to a later time, when the details of the dynamo must be designed. The reason why it is not necessary to go very closely into the question of leakage, for the mere purpose of estimating the cost lies in this, that a few per cent. more or less leakage does not materially alter the output. Professor Forbes has shown us a diagram suggesting a new method of placing the exciting coils, by which he hopes to nearly do away with leakage. No doubt this object would, to a certain extent, be attained; but the greatest merit of his suggestion lies in the fact that wire will be saved provided the system is used on dynamos having long armatures of small diameter. This design labours, however, under the great practical difficulty of either having to bend the coil up at the ends of the armature or extend it so as to enclose the commutator and brushes, which would again increase, to a certain extent, the amount of wire. The latter difficulty could be overcome, without sacrificing any of the theoretical advantages, by adopting a design for a four-pole dynamo which

Mr. Kapp. I published in the *Electrician* about a year and a-half ago, and which is shown in the diagram :—



There are only two coils employed which are of the usual construction and can be wound in any ordinary lathe. Each half of the machine to the right or left of the vertical centre line is virtually a Forbes dynamo, but each coil, instead of being wound in a vertical plane having to cross the armature, is wound in a horizontal plane. To make this design economical, the diameter of the armature should be large as compared to its radial depth, and the vertical cores of the field magnets should be as short as possible, the only consideration being to provide sufficient space for getting a reasonable length of coils. Curiously enough, this design has actually been adopted by Mr. Kennedy of Glasgow, who makes what he calls an iron-clad dynamo; also, to-day, Mr. Elwell, of Wolverhampton, called on me and asked whether this was really the arrangement described by me in the *Electrician.* He had made a machine in Wolverhampton exactly on the same principle and found that it works exceedingly well, giving a large electrical output for very little weight and expenditure in labour. You can see that the cost for labour and

material in this four-pole machine is very much less than in the usual form, where you have to tie the magnets together with stays of gun metal. Another advantage is that the machine is absolutely rigid. Dr. Hopkinson has described his method of measuring maximum induction, or, as I call it, the maximum number of lines which can be got through a square inch of iron. Another method occurred to me, and if I had been with Mr. Crompton I would have employed it, and given the results in the paper. It is only applicable with double horse-shoe machines, and I hope Mr. Crompton will make the experiment. In the former Crompton machine the poles were made bulging out, but in the modern machines their external surfaces are straight, so that the thickness of metal in the centre of each is very much reduced. The experiment would be made in the following way: Remove the armature and alter the coupling of the exciting coils so as to produce continuous magnetisation without external poles. The magnetic circuit will then be completely through iron, and the lines will crowd through the reduced section of the pole-pieces, where saturation will be produced with a comparatively low exciting power. Wind a single turn of wire round the part thus saturated, and connect it with a ballistic galvanometer. The induction can then be found in the usual manner by observing the throw of the galvanometer, whilst the exciting current is made or broken. Mr. Kapp.

Mr. Walker said something—in fact, a great deal—about leakage, and he, like all others, has over-estimated the danger of leakage. I think that leakage is now in a fair way to be regarded by electricians as a great bugbear, and other things will be sacrificed in order to reduce leakage. I do not think that leakage is so very bad as some speakers would make it appear. If the leakage were 25 per cent., we need not waste 25 per cent. of the exciting energy. The amount wasted depends on the cross section of the field magnet. Say that a magnet 4 inches by 10 inches would suffice if there were no leakage; if there is 25 per cent. leakage, the magnet would have to be 5 inches, and the perimeter, or length of one turn of exciting wire, would have to be increased by 2 inches, the total being about 30 inches.

Mr. Kapp. This increase is only about 7 per cent.; and the exciting energy required to produce an additional 25 per cent. of waste field will only be 7 per cent. greater than if there were absolutely no leakage.

Professor Thompson, in his introductory remarks, found fault with the scope of the paper, because it was not a paper on the characteristic of the dynamo at all, but on the magnetisation of a dead piece of iron. Well, that is true, but I did not mean to go to-night through and write a treatise on dynamo construction, showing all the geometrical problems which might be solved to deduct one curve out of another, because I thought that was a thing too elementary for an institution like the Telegraph-Engineers.

It is very curious that most speakers have said something rather disparaging of the Frölich curve [*the dotted line in Fig.* 3], but, curiously enough, the severest condemnation came from Professor Thompson himself. He said that no man in his senses would work a dynamo at half-exciting power, and that the point (A) I have chosen in the curve was wrong. He forgets that, whether you like it or not, you are bound sometimes to work your machine at half-power. Suppose you want to make a machine to give you 130 volts at full output, and 100 on open circuit, so that it may properly regulate at 100 volts at the end of a long circuit; or, take the case of a shunt machine driven from a shaft in the factory, which does not run at a steady speed, and requiring therefore an automatic regulator, so that it gives the maximum output with a minimum of speed, and *vice versa*, at the same pressure. It is quite possible that in such cases the machines would occasionally work with less than half the exciting power. Professor Thompson said that if I had chosen the point higher on the curve, Frölich's curve would have answered very well for saturation. Of course it would, because I should verify at the same point as that originally chosen. But if a curve is to be of any use it must represent the actual condition of the machine over a reasonable distance; and if Frölich's cannot fulfil this requirement it must be condemned.

Now I must say something about a subject which makes me

feel very uncomfortable, and that is the question of units. I need **Mr. Kapp.** hardly say that last Thursday my heart sank within me when I heard one speaker after another disapprove of them. Professor Thompson said that my system is an inextricable mixture of centimètres, grammes, minutes, and inches. Now, I protest against this; my system is no mixture, for I do not use centimètres, grammes, or seconds. I use minutes, because everybody is accustomed to counting revolutions per minute; and anybody quite unacquainted with French measure can work my formulæ, and would at the same time see what he is doing. The figures are of reasonable magnitude, and present to those who use them a definite meaning. They know what is meant by 17 lines to the square inch, but if we talk of 15,800 to the square centimètre a greater mental effort is required to grasp the meaning.

Last week, after Professor Thompson accused me of using a mixture, we had an example of how easily the C.G.S. system leads to misunderstanding, for one speaker called that a gauss which another called a milli-gauss—the proportion between the two being nothing less than one to a million. It is significant that practical dynamo makers have not raised any objection to my system of units. The translation from it to C.G.S. units is really not such a very difficult matter as we are told, and with a little training one could get to manage either system equally well; but we have to talk to our workmen, and then we could not use grammes, centimètres, and seconds. We must give them figures in the usual English measure, and therefore it saves labour if we make the calculations in a system where the figures are of reasonable magnitude and directly applicable to the various purposes of the workshop.

The following paper was then read:—

SOME EXPERIMENTS ON SECONDARY CELLS.

By James Swinburne, Member.

This paper is a very condensed account of a large number of experiments made in the spring of 1883.

Abour four years ago Mr. Norman Cookson, of the well-known

firm of lead manufacturers in Newcastle, brought out a process for making lead in the form of fine fibre or hair. Mr. Cookson's method is this: The lead is melted in a pot which is raised some feet from the ground; from the melting-pot is a tube which leads down some six feet, and ends in a rose like that used on a garden watering-can. The fall tube is kept hot throughout its length, so that when the lead is melted in the pot it is not solidified in the pipe. The melted lead then flows through the fine holes in little jets, and these jets solidify in the air, and fall in a tangled mass like lead moss. Some care has to be taken to keep the lead in the pot and in the tube at the right temperature, but this is the only difficulty, and the whole cost of the lead hair is not more than two shillings per ton above that of pig lead.

Those who were working at secondary batteries this time four years ago will remember that most people had the idea that the great thing to be aimed at was a very large surface. Mr. Cookson's invention, therefore, seemed most valuable, and he set to work with the energy which is his characteristic, especially when working at something new. Mr. Cookson made up a dozen large cells, which he sent to Mr. Jameson, the inventor of the coke process, who was then working at an incandescent lamp. Some of the lead hair was made up into little cells, and tried in various ways by Professor Herschel, of Newcastle. Professor Herschel published some account of his work in *Nature*. Mr. Cookson also made arrangements with the writer to go into the question of secondary batteries. The theory that large surface of lead was necessary gave way when the question of local action was more fully studied, but after all it seems to be near the truth.

Some reason may be demanded for bringing before this Society the account of experiments which were made so long ago. Many of them have been made again since, and many are of no use at all; but, on the other hand, there are a number which are still new, and the next best thing to knowing what to do is knowing what not to do. We made altogether more than three hundred different cells; but, to prevent this paper running to too great a length, only a few of them are described.

Cells with Hair Lead.

The first were Mr. Cookson's large cells. These had four plates; each plate was about 8 in. by 10 in. by 1 in., and consisted of a sort of cage of sheet lead with holes in each side. The lead was joined by burning, no solder being used. The inside of the cage was filled with lead hair, a lead wire being arranged zigzag through it, and burnt to the cage. Each plate was sewn in flannel. A battery of twelve of these cells was sent to Mr. Jameson to be charged. They came back to the lead works without any particulars as to what had been done with them. We therefore coupled them up with a dynamo, and charged them in what appeared to be the opposite direction. They had 12 ampères through them for about seven hours a day for no less than five months, and even after three months gas was coming off the reduced plate only. The cells seem to have had enormous capacity, and must originally have been charged in the other direction. After three months the reduced plate gave off gas, but the peroxide plates went on charging for the whole five months. We did not try running them down to see what charge they really had, as other experiments which were going on at the same time led us to suppose that the local action would render them useless. Probably the surface of these plates was so large that the local action formed enough sulphate of lead during the night to utilise the current during the whole of the next day in oxidising it. At the end of the five months the flannel round the plates was not spoilt. This seems to show that it is not the acid that spoils the flannel in the Faure cells, but the oxidation due to the contact of peroxide of lead. Some experiments on organic substances with oxidising agents will be described presently.

The first difficulty to be overcome with the Cookson lead hair was making good electrical connection with the support. Various methods of soldering were tried, but the little wires of lead were melted off whenever it was tried to burn them to the back. Solder with a flux of caustic soda ran along the fibres too much. Various methods of connecting the fibres by pressure were tried. The material was woven into loose mats, and these were passed under large rollers. Every degree of density could be obtained in this

way. Though the metal was clean, and appeared to stick together at first, it did not adhere as strongly as might have been expected. The chief fault of the lead hair seemed to be the vice of local action. In those days local action was not so well understood as now. The theory seems to be this: If lead and peroxide of lead are electrically connected, and any of the surface of the lead is exposed to the acid, that part of the surface is attacked, and a thin film of lead sulphate is formed which protects the surface from further corrosion. The lead is then in contact with the peroxide at some points, and with lead sulphate at other points, but is not touched by the acid anywhere. If the cell is charged further, the film of lead sulphate is oxidised into peroxide, so that the plate again consists of lead and peroxide of lead only. As the peroxide formed from a given quantity of lead sulphate occupies much less room, a small portion of the surface of the plate is again exposed, but is immediately coated with a film of peroxide; the result is that the whole surface of the plate is protected. The least movement seems to expose some of the surface of the lead to the acid. The lead can thus be protected by anything that prevents its contact with the acid. For local action to take place some of the lead must be exposed to the acid. If, while a cell is charging, a clean surface be made on the peroxide plate it will immediately be covered with a thin film of peroxide which will protect the plate from further attacks. If, on the other hand, the dynamo is disconnected and a clean surface then exposed, it will be immediately covered with a film of sulphate which will protect the plate. Thus the plate may be protected either by sulphate or peroxide. When the lead of a plate is converted into peroxide the plate is being charged. When the lead is converted into sulphate local action is going on. In the large Cookson cells the fibres of lead were converted into peroxide during the day by charging, and more lead was converted into sulphate during the night by local action; so that it was unnecessary to reverse the batteries to secure more rapid formation, the formation being already rapid enough. Mr. Crompton told me this summer that he found that cells were practically indestructible if not discharged too much, and this seems to be the grand secret of successful work

with secondary batteries. Messrs. Drake and Gorham mentioned the same thing in their paper read at the British Association this autumn. Either the peroxide of lead is so porous that it never quite protects the plate, or it is disturbed by small bubbles formed in the coating; for if a current is passed continually in one direction a lead plate is eaten into, as may be seen in a water resistance with lead electrodes—the oxidised plate seemingly does go on forming. In the lead hair cells the surface exposed was so enormous that a very slight formation was enough to demand a very large supply of electrical energy, so that the cells seemed to run down as fast as they were charged. No doubt the fault was that the fibres of lead used were rather too fine; if we had used much thicker lead wire we should have probably made a very good battery. Several plates were tried with hair lead, red lead, litharge, &c., but our ideas as to the validity of Faure's patent were not quite what they are now, so comparatively little was done in that direction.

Secondary cells are, however, tedious things to experiment upon; it may take a year or so to see what a cell is going to do. The best method is to keep several sets of experiments going on at the same time.

For the sake of conciseness some of each class will be given, arranged in groups.

Quick-forming.

Cells were made with lead hair in a solution of sodium chloride: the anode was quickly attacked, but the coating was not adherent, and came off in clouds; black clouds, presumably of finely-divided lead, came off the other plate.

Lead hair and potassium bichromate: seemed to oxidise well.

Lead hair and potassium sulphate: no very marked result.

Amalgamated lead in dilute sulphuric acid: the peroxide formed had little stiction or power of adherence, and kept peeling off and exposing the bright amalgamated surface; this happened especially on reducing.

The object aimed at was to get an electrolyte which partly dissolved the plate; the idea being that an action like that of

which advantage is taken in the manufacture of white lead might be used in the quick formation of battery plates.

Lead in solution of sodium-thiosulphate: thick black mud of lead sulphide formed.

Amalgams of lead and 10 per cent. and 5 per cent of mercury: coating had no stiction.

Alloy of lead and zinc: this was not so easily attacked as one might expect.

Lead hair in solution sodium hydrate and sulphide: the solution got yellow, and deposited sulphur on the oxidised plate.

Lead in solution of ammonium chloride: was no better than the similar cell with sodium chloride. No doubt a little nitric acid was formed, but the cell was not a success.

Cells were tried with solutions of potassium fluoride: the plates were not formed well.

Lead in potassium sulphides: not much attacked; the action of the sulphide seemed uncertain, and is partly dependent on the amount of hydrate present.

Lead plates in solution of salt, with felt between: after reversal this gave good spongy lead, but a great deal of the peroxide was loose and detached.

Lead with various mixtures of sulphides and carbonates and nitrates: none of these gave deposits which would reduce well—they were all too loose.

Lead in sulphuric acid: just diluted enough to make it conduct; the anode was not much attacked.

Lead in a mixture of sulphuric and nitric acids: more quickly formed.

Lead in nitric acid alone: eaten through very quickly. The action of nitric acid on a lead plate is very peculiar. Most of the solutions already mentioned attacked the plate evenly and oxidised it gradually through, but nitric acid makes pits and round holes. As nitric acid seemed by far the best means of quick formation, several experiments were made with it. Plates were eaten wholly through with acid which was too strong to dissolve much nitrate; the acid was then siphoned off and replaced by a solution of sodium sulphate and reversed. There was difficulty in reducing

the lead sulphate; it formed cakes which did not make good contact with the plate. The great objection to the various methods of forming above described is that the coatings produced have too little stiction to reduce well. When lead was the anode in nitric acid no peroxide was produced. Of course no peroxide is formed when the plate is in contact with sulphuric and hydrochloric acids, as peroxide of lead liberates chlorine in an acid solution, while chlorine precipitates lead peroxide from an alkaline solution of the lead salt.

The best solution we tried for forming plates was a mixture of dilute sulphuric and acetic acids: this solution made a fine and adherent coating which reduced well. One of the most obvious disadvantages of such solutions as dilute nitric acid is the difficulty of getting rid of the least traces of acid; of course, traces of such things as nitric or hydrochloric acid in a cell may be very destructive, or they may be quite harmless. Acetic acid can easily be driven off as vapour, and nitric acid might perhaps be reduced to ammonia and then volatilised.

Mr. Brush heats his plates to accelerate their formation; we did not try this.

Local Action.

To reduce the local action in the peroxide element we tried amalgamating the plates: this did not act. We tried to gild lead plates, but did not succeed; a gold sleeve-link seemed to act well as a support for a little peroxide plate, and it was hoped that gilding might preserve lead. We tried to protect lead by various sulphides. These experiments seem absurd; in fact, many of our experiments were rather wild; but the supposed method of protecting plates has recently been patented by no less able a chemist than the late Mr. Tribe. Lead was fused with various proportions of galena, and the resulting substances were tried as anodes. Galena itself is at once coated with lead sulphate when used as anode in dilute sulphuric acid.

Lead was also combined with arsenic by heating in glass tubes: this was very troublesome work, as the arsenic was apt to volatilise, and sometimes the tubes broke, and the laboratory had to be abandoned until the smell was gone.

Double sulphides of antimony and sulphur bases were tried, but were of no use. In our provisional protection applied for in 1883 we mention coating the plates with lead sulphide by means of thiocarbamide. This idea was taken from a receipt seen in a copy of the *Plumbers' Times and Paperhangers' Gazette*, or some such paper, which was sent me with an intimation that I had no business not to take in my trade journal. Thiocarbamide could not be bought, and was too troublesome to make, so this plan was not tried. The process is said to produce a beautiful polished adherent coating of lead sulphide on lead, or even on organic substances such as netting, and is of very considerable interest, and perhaps of commercial value.

Silver was tried as peroxide plate in various solutions. It behaved very much like lead, though it is not so easily attacked by sulphuric acid; peroxide of lead sticks to it well, but of course it is too expensive for commercial use. Silver might be used for connections. Most metals exposed to the action of the spray from secondary batteries are attacked, and make bad contacts, but silver may be laid across the top of a cell without tarnishing. Probably electro-plated copper would do as well. Very few experiments were tried with platinum because of the expense. Mr. Brush has patented plates made of an alloy of lead and platinum. Most likely it would take a very large proportion of platinum to protect a plate, as the alloys of platinum are easily oxidisable. No doubt Mr. Brush's invention is only waiting for the discovery of a platinum mine.

Local action may be a very serious evil in reduced plates, especially with strong acid. In some cases reduced plates in dilute sulphuric acid give off little bubbles of gas continuously for a couple of weeks. Spongy lead seems to have very nearly strong enough affinity for the electro-negative radicle of sulphuric acid to combine by evolving hydrogen, more especially if the acid is strong. It seems likely that traces of some metal even slightly negative to lead may start local action. Platinum and lead, for instance, decompose dilute acid at once; but perhaps traces of arsenic or antimony in the oxides from which the reduced coating has been made, or in the acid, may sometimes produce the same

result. Peroxide of lead, on the other hand, is more stable though when heated with strong sulphuric acid it seems to evolve some oxygen and turn lighter in colour.

Electro-gilded copper was attacked at once by sulphuric acid.

Carbon for Peroxide Plates.

The practice of making peroxide plates of carbon does not seem to be quite abandoned even yet. Carbon is more easily oxidised than is popularly supposed; in fact, Brodie's process for disintegrating graphite depends on the action of an oxidising agent. We tried some Faure plates with carbon in dilute sulphuric acid and in a solution of zinc sulphate. In both cases the carbon was attacked. After standing for some days the peroxide plates seemed quite good, and the peroxide appeared to stick well to the carbon and to form good coatings. On examination, however, it was found that the carbon under the peroxide was converted into a soft black pulp. Carbon was tried as anode in various solutions, such as sodium carbonate, sodium phosphate, phosphoric acid, dilute sulphuric acid, potassium fluoride, potassium sulphide, hydrochloric acid, liver of potassium, potassium chromate, ferricyanide, ferro-cyanide, permanganate, borax, potassium tungstate, potassium hydrate, sodium chloride, &c. In all cases where oxygen would otherwise have to be evolved the carbon was attacked, but when a current could pass by evolving chlorine the carbon was not attacked. As peroxide of lead acts on a chloride in an acid solution, carbon is evidently useless for peroxide plates. It may do admirably for bleaching or evolving chlorine or making hypochlorites. The same conclusions were arrived at by Bartoli. Biscuit, or unglazed porcelain, impregnated with carbon deposited from hydrocarbon by heat, was tried: it split into small pieces. It is odd that none of the sufferers from primary battery disease have used this material for porous pots, as many of them have the idea that a carbon porous pot somehow reduces the resistance of the cell.

As no metals were available as indestructible supports for the oxidised plate in dilute sulphuric acid, and as carbon also appeared useless, the next thing was to try to make the supports

of peroxide itself. Peroxide made by oxidising coatings made originally from litharge or red lead was not hard enough to make good supports; but the peroxide deposited by electrolysis of an alkaline solution of a lead salt was very much harder. The best way seemed to be to make a paste of litharge and caustic soda, and to attach it to the lead plate and make it the anode in a solution of caustic soda. When the whole of the litharge was oxidised the lead plate was removed. The resulting peroxide was very hard, and seemed quite impervious; when a bit was used as a plate in a cell, and the cell discharged, it ran down at once, the peroxide being covered by a very thin film of lead sulphate. The surface seemed to be the only part in contact with the acid. It would be a matter of great practical difficulty to make cells with peroxide supports commercially. It would be interesting to know how this form of peroxide compares with Mr. Fitzgerald's *lithanode* in point of hardness and durability. The peroxide from a solution of nitrate and tartrate of lead looks very dense and hard, but it comes in the form of scales resembling iodine. Before leaving the subject of lead plates some experiments on lead sulphate must be described. It was supposed at one time that lead sulphate could not be reduced in dilute acid. Sir William Thomson had made experiments with it, and had found it would not reduce. We made a cell with platinum plates and precipitated lead sulphate in dilute sulphuric acid; it was charged for five weeks, and at the end of that time the sulphate on one was completely oxidised, but on the other it was only reduced here and there in spots. A similar cell was then started with a little litharge mixed with the sulphate: the sulphate then reduced perfectly. This is a result of some importance. The reduction of sulphate seems to be purely a question of good contact. In many cells which gave very small outputs the reduced plates were found to be in fault. The slightest film of thoroughly-formed sulphate acts as a perfect insulator. It is a good plan to keep a small cell always ready with both plates fully charged; then, when a cell under test runs down, each plate is separately tried with a proof plate, and it is then found which of the plates has failed. The film of sulphate formed on a piece of

lead reduces all right, but as sulphate of lead is very bulky its formation seems to cause buckling about and resulting bad contacts. To see how great the swelling due to the formation of sulphate of lead is, the specific gravities were taken, and the following are the resulting figures :—

100 volumes of lead form—

Peroxide of lead	160
Red lead	148
Litharge	151
Lead sulphate	297

This shows that lead converted into sulphate swells into three times its original bulk, and that peroxide on becoming sulphate is doubled in volume; this at once shows why coatings tumble off plates. To see how much of the active material in a cell is really used, several plates were made up with weighed quantities of lead oxides. One of these was a little Sellon plate, made of a piece of a large plate filled with minium or litharge; others were Faure plates. After charging, the plates were short-circuited through copper voltameters. The maximum output was from 5 to 7 per cent. of that calculated.

Many attempts were made to make coatings that would stick well. Collodion was of no use; litharge and sugar did not make good coating; sodium silicate mixed with the litharge before applying was useless. Litharge and glycerine form a very useful cement known as engineers' cement. Though the coating was very easy to manage, there seemed to be no permanent advantage in using glycerine. This coating has been patented. In those days it was usual to wrap plates in flannel to keep the coating on. The flannel generally went to pieces very soon; it appeared, however, that this is not due to the action of the acid, but to oxidation through contact with the peroxide. Asbestos paper is too weak to be of any use. Cotton or linen is soon destroyed by acid, but resist strong alkali longer; while flannel resists acid, but is attacked by alkali. Pyroxylin is easily attacked by alkali, not easily by acid. Tribe proposed to use pyroxylin for supporting plates. Xylonite has also been tried for

me more recently by Mr. Cathcart, then my assistant. It is much the same as celluloid, being made of pyroxylin and nitrobenzole, camphor, or some such solvent. This will stand being boiled in moderately strong sulphuric acid for a long time, and should be very useful in battery work. Flannel was soaked in collodion, with the idea that the fibres might thus be protected, but they were not. Flannel was also soaked in sodium silicate and attacked with sulphuric acid: it succumbed.

Strength of Acid.

It was usual to use acid of a strength of 1 to 10. This probably arises from that being the strength in vogue for Daniell batteries.

The strength of acid was also not considered, because the action of secondary batteries was for some unaccountable reason supposed to be due to the formation of litharge on both plates. I am afraid Dr. Lodge was much to blame for perpetuating this error. Another absurd theory was that the action is due to occluded hydrogen in the reduced plate. It has been said that the study of secondary batteries belongs to chemists, not to electricians; but it is strange that when chemists have to deal with electrolysis they seem to forget their chemistry, or to imagine that the laws of chemistry no longer hold good. As the action of the cell depends on the formation of lead sulphate, it is clearly an advantage to have as much acid as possible available in the coatings.

On looking into Gladstone and Tribe's book on secondary batteries they are found to state that the action on the peroxide plate is as follows:—The peroxide is reduced to monoxide, and the sulphuric acid then combines with this to form lead sulphate and water. If this were the case the energy due to the combination of the lead with the sulphion would be entirely converted into heat, not into electrical energy. Chemists have a lot of time-honoured ideas which do not at all fit the facts of electrolysis. One is that salts are formed by the combination of an acid and an alkali. In old days people spoke of the sulphate of the protoxide of lead and so forth, and lead sulphate was

represented as PbO,SO_3 when it was understood that the water was eliminated. Even now chemists seem to assume, without foundation, that a metal cannot form a salt without passing through the intermediate state of oxide, though really an oxide is itself just as much a salt as a nitrate or sulphate. If electrolysis proves anything at all it is that a salt is made up of an electro-negative and an electro-positive radicle, not of a base and an acid with some water eliminated. The action of an acid and an alkali is simply the exchange of radicles, the most electro-negative radicle combining with the most electro-positive, making a salt in which neither preponderates, or, as it is called, a neutral salt.

If the coatings have only weak acid it may be all absorbed when the cell is discharged a little, and the electro-motive force will fall, and there will be a tendency to the formation of basic salts in the coatings; but, on the other hand, if the acid is made stronger, it may be decomposed without electrolysis, as when peroxide of lead evolves oxygen and forms lead sulphate, or as when spongy lead evolves hydrogen and forms lead sulphate. In the case of spongy lead there may or may not be electrolysis. If the acid is so strong that the lead decomposes it directly, there is no local action; but if there be some more electro-negative metal, such as, say, antimony, in contact with it to evolve the hydrogen, there is electrolysis.

Another universally accepted theory without any foundation is that all electrolysis is due to the action of nascent hydrogen or oxygen. In old times when someone saw bubbles coming off zinc in an acid solution of, say, an iron persalt, and found the persalt was reduced to a protosalt, he naturally supposed the gas was the cause of the action. But there is no reason to suppose the hydrogen has anything to do with it. It takes a certain electro-motive force to give off the hydrogen, and a certain less electro-motive force to reduce the persalt. If the available electro-motive force is between these values, the persalt will be reduced without any hydrogen being formed. To suppose that hydrogen is first formed, and that the thing then changes its mind and does an easier chemical action, is unphilosophical.

The combination of the zinc with the available negative radicle will go on, the action being made possible by the reduction of the persalt when present, and by evolution of gas when no persalt is present at that spot. The nascent gas idea is like saying that when one goes up to the first floor one goes to the roof and tumbles down again to the first floor.

Still further reduction takes place in thousands of ordinary chemical actions where no hydrogen is present, as when carbon monoxide is passed over hot litharge. Again, electrolysis takes place quite well without hydrogen or oxygen being present as when a fused metallic chloride is electrolyzed.

Another unfounded theory is that it is the water that does all the conducting, and that it is first decomposed, the other action being secondary. Pure water does not conduct, neither does pure sulphuric acid, but the mixture does; how, then, is it inferred that the water only of the mixture conducts? No doubt the only way to study electrolysis is to divest it of all preconceived theories that have no logical foundations, and to study thermo-chemistry.

The best strength of acid was not determined by us, and it no doubt depends on the purity of the lead, and of all the compounds forming the coatings, and of the acid itself. It also depends on the way the cells are to be used. If the acid is strong, both oxygen and hydrogen will be given off slowly, even during several weeks. As the idea of using secondary batteries as magazines for storing energy for long periods is being given up, this slow decomposition is of little importance; but there is another point—that is, that sulphuric acid which is not very dilute separates into two strata of different specific gravities. Before leaving the subject of lead cells, it may be as well to mention that the troublesome spray that comes during charging may be prevented by floating paraffin on the top of the acid. The spray not only tarnishes, rusts, or destroys everything near, but is the cause of all sorts of ground leaks. The paraffin prevents the acid from creeping; in fact, it creeps itself, and acts as an insulator.

Alkaline Cells.

It is well known that iron is very electro-negative in an alkaline solution; but such solutions as that of caustic soda or potash are not available, because nearly all salts of lead are soluble in them. It was therefore attempted to make cells with iron supports in an alkaline solution of some salt whose acid radicle would not attack iron, and would precipitate lead salts. Iron in solutions of potassium cyanide, ferro-cyanide, and ferri-cyanide was attacked; the ferro-cyanide or yellow prussiate of potash plate was least eaten. Even such salts as sodium sulphate dissolve some lead sulphate. This property is important in connection with ordinary secondary batteries. A little sodium sulphate mixed with the acid may tend to make the sulphate of lead more easily reduced; as, when all the sulphate is reduced that is in contact with the support, hydrogen is evolved, and caustic soda is formed in the immediate neighbourhood of the plate, and can dissolve the sulphate, the lead being then precipitated as spongy lead. The spongy lead can thus make contact with the sulphate. Magnesium sulphate has been recommended as a solution, but it is difficult to see why. Zinc sulphate might be good.

Alkaline sulphides of course attack iron.

Iron plates with coatings of white lead in solutions of sodium carbonate: these oxidised and reduced very well, but the iron seemed to be slightly attacked. On testing the peroxide, traces of iron were found. Thinking the corrosion of the plate was perhaps due to impurities in the carbonate, such as sulphate, experiments were tried with the purified salts. The iron seemed to be in a sort of unstable state. Sometimes it would remain quite clear and bright in contact with the peroxide, and with bubbles of oxygen evolving from its surface; but suddenly a green spot would appear, due no doubt to the formation of carbonate of iron, and this spot would extend and cover the whole plate. The best results were got with bicarbonate of soda.

Nickel was tried in the same solutions: it behaved in the same way, though it was not quite so easily attacked. The carbonate was lighter in colour, being apple green.

Iron plates with borax solution: green discoloration.

Iron plate with caustic, potash, and tannin: iron eaten.

Some cells were tried with iron plates and ammonia; but as it is probable that nitric acid would soon be formed in them they were abandoned. The alkaline cells gave 1·7 volt. The measurements were taken roughly. A calibrated tangent galvanometer was used as a voltmeter; for measuring currents a low resistance was made up consisting of a lot of wires put in parallel, their resistance having been measured in series.

Ammonia sometimes gave a brown deposit with iron plates.

As it seemed hopeless to get iron to stand without being attacked, various methods of protecting it were tried. Iron gauze was coated with peroxide by making it the anode in a solution of litharge in caustic. When this solution is electrolised clouds of litharge are evolved close to the plate. This is very curious, for if the solution is plumbite of lead the electro-negative radicle would be $Pb\,O_2$, not $Pb\,O$; such a salt being presumably $Na_2\,Pb\,O_2$. Peroxide of lead deposited from solution of litharge in caustic is too dense to be used as an active coating; it was proposed to use it to protect the iron, and to have then applied a coat of porous peroxide such as is used in acid cells. The peroxide was never satisfactory. To make up for the imperviousness of the peroxide, red lead and water were rubbed into the pile of velvet; the velvet was placed with its face against the iron plate, and the coating was oxidised in an alkaline solution. The velvet was then dissolved out by strong alkali, so as to leave a coating with a very large surface. This plate, however, had very small capacity. Electro-gilding the iron was then resorted to. It is a little difficult to gild iron, as the gold does not stick well. After each coat of gold the iron was heated to make the gold sink in. The gilded plates did not answer well. The Bower-Barff process for protecting iron from rust was tried, by getting an ornamental railing top and making it the anode in a cell. The black oxide did not prove to be a good enough protection. The strange thing about the corrosion of iron in alkaline solutions is that it does not take place if there is no coating. A piece of sheet iron may be used as anode in the solution of carbonate or bicarbonate of soda

without being the least corroded; but if a coating of, say, white lead is applied, green spots appear at once, but only under the white lead; the back of the plate remains quite clear. Oddly enough, sheet tin is not easily attacked by an alkaline solution. Sometimes it turns black, or the surface, which consists of an alloy composed chiefly of tin, peels off in black scales. Sheet tin behaved much as iron and nickel; that is to say, it behaved very well till a coating was put on, and then it was corroded. There is a very curious alloy of iron and tin. If iron and tin are melted together, the resulting alloy separates into two portions; one is approximately Fe Sn, and the other consists chiefly of tin, and has a low melting point. The alloy Fe Sn solidifies at a red heat. It was too unmanageable to be of much use for batteries, and it was no better than sheet tin; but it was so hard that a straw-hardened cold chisel even would not cut it, but broke in pieces, while a softer chisel turned up at the edge. This alloy might be useful in commerce. The writer has since tried to make more of this alloy for some experiments on persistent magnetism, but has never succeeded in making it so hard again.

Iron without a coating is not attacked in such solutions as potassium bichromate, or permanganate. At first sight this seems strange, but it must be remembered that such salts owe their corrosive properties, especially when acting on organic bodies, not to the strength of their acid radicles, but to the electro-positiveness of chromium and manganese, which makes them combine energetically with an acid radicle to form chromium or manganese salts. Thus potassium bichromate or chromic acid in the presence of sulphuric acid is a very powerful oxidising agent, but if there is no acid present to form a chromium salt it is no longer energetic. Iron in alkaline solutions is very convenient for adjustable water resistances.

We worked at iron cells with some tenacity, because we seemed to be very near success; and if we could make a peroxide plate with iron without local action, the negative might be of zinc, as this combination gives a high electro-motive force.

Cells with Zinc.

Evidently cells with zinc could not be used in most acid solutions, as so many of its salts are soluble. Secondary batteries with zinc plates have often been brought out; but as the zinc dissolved on discharging is not deposited on the same part of the plate on charging, these cells cannot well be used very often. M. Reynier has lately worked at cells with zinc in sulphuric acid, and Planté peroxide plates. He does not say how he proposes to get over the difficulty of the zinc being deposited in the wrong place. He says that the deposited zinc is so pure that there is very little local action. His cells give 2·37 volts.

We tried plates with reduced zinc coatings in alkaline solutions that do not dissolve zinc, such as sodium carbonate and sodium bicarbonate. The coatings were made of oxide or carbonate of zinc. The chief trouble was the proper reduction of the zinc. These salts of zinc behave very much like lead sulphate—that is to say, they are very bulky—and the coatings form hard white cakes which are not in good contact with the support. When the zinc is eventually reduced it is very soft and loose. Very likely we made a mistake in reducing coatings of oxide or carbonate of zinc, instead of forming the coating out of the solid plate by attacking it when used as anode. The object aimed at was the use of iron for the support of lead peroxide in the other element; but as we did not get iron to work satisfactorily, we did not do very much with the zinc.

Primary Cells.

A few experiments were made, but they are not worth recording. Lately, however, the writer saw a note in the *Electrician* to the effect that a French *savant* had used agar-agar jelly in a Leclanché cell. It seemed possible that the use of this might avoid the necessity for a porous pot in a two-fluid cell, the idea being that to make up a cell one might take a zinc plate, place on it a wad of zinc sulphate jelly, place on that a wad of copper sulphate jelly, and cover it with a copper plate. Zinc and copper jellies are easily made, but the drawback is the rapid diffusion of the copper salt. Some cells were made with zinc

filings suspended in the zinc jelly, so that any wandering copper salt might be caught before it reached the zinc plate. As rapid diffusion is always the result of a low-resistance porous cell, it seems useless to try to make a low-resistance two-fluid cell unless some colloïd oxidising agent can be found. Some of the solutions of iron were found by Graham to be colloïdal; perhaps something might be done with them.

A bichromate jelly cell was tried, but it was also a failure. The same thing was noticed as in the case of flannel and cotton. Bichromate jelly with no acid keeps for any length of time; and sulphuric acid jelly can also be made; but the jelly dissolves at once if both acid and bichromate are present. The same thing happens with potassium permanganate.

Agar-agar is a fucus or sea-weed. It has, if the writer is not mistaken, the same composition as starch. It has a very high gelatinising power—about ten times that of gelatine. It is probably used for sizing paper or calico, or for cooking. Mr. Stanford, of Glasgow, is an authority on the uses of sea-weeds.

Gelatine was tried, but it was liable to go bad, and was at once attacked by oxidising agents.

Probably gelatinous silica may do, but the writer has not yet made enough experiments to say. A low-resistance bichromate cell in which the bichromate had not access to the zinc would be very useful where a large power is occasionally required, as in the laboratory.

Miscellaneous.

While various cells were being charged or discharged there were often odd quarters of hours to spare. These were spent in trying different experiments not connected directly with secondary cells.

White Lead.

It was attempted to make white lead electrolytically. The present method of making white lead, which is felicitously termed the "Dutch process," is slow and barbarous, and exceedingly unhealthy. The women who are continually among the white lead absorb the lead through their skins, or perhaps swallow it little by little, and are apt to suffer from lead poisoning. Messrs.

Cookson & Co. have probably the best sanitary regulations and arrangements in the world; but even then the Dutch process is very dangerous.

To make white lead electrolytically, plates of lead were made anodes in solutions of carbonate or bicarbonate of soda, with very small currents. In many cases white deposits were obtained, but in no case was any quantity obtained. If the current was increased the plate was soon coated with a brown compound. To imitate the action of the basic acetate a little acetic acid was added to some of the solutions. In some cases a very curious phenomenon was seen. Long white columns like small candle drippings started about the middle of the plate, and grew down to the bottom of the beaker. The plates were about three inches from the bottom.

Experiments were tried with lead plates and solutions of salt with a view of making white oxychloride of lead. The plates were of course easily attacked, but if the current was very small the coating formed very slowly, and appeared crystalline, and if the current was increased the coating turned brown.

Sodium Chlorate.

Potassium chlorate is very largely used for making English matches, and in dyeing; it is probably used instead of sodium chlorate because it can easily be separated from chloride by crystallisation. To make sodium chlorate, solution of salt was electrolyzed. This gives off chlorine at the anode, and various salts, such as sodium hypochlorite, are formed. If sodium hypochlorite is boiled it gives chlorate and chloride. We prepared a mixture of sodium chloride and chlorate, but the percentage of chlorate was too small for the process to be valuable.

Aniline Dyes.

There may be a large field for the application of electrolysis in the aniline industry.

A cell was tried with aniline, but it would not conduct.

A cell was tried with phenol, but it would not conduct. Potassium hydrate was therefore dissolved in the phenol to make it conduct. A black compound was formed at the anode.

These last experiments are not brought forward as of any value, but they are instances of applications of the dynamo to very different industries. Now that we have the dynamo as a commercial machine, we seem to be resting content with one very small use for it. We use it almost entirely for the electric light. Though it is quite well understood that power can easily be transmitted electrically, the use of motors can hardly be said to be pushed at all. Engineers have only to be shown motors at work to see what beautiful, smooth, and silent-running things they are, and they will be applied in thousands of instances. The dynamo is now being introduced for the treatment of argentiferous copper; but this is a comparatively small industry. The electro-plating fraternity are a very peculiar people. Though constantly using it they seem to know as little about electricity as medical men. Before electricians can meet them on common ground they must give up talking of the strength of the quantity of current from seventeen Smee cells.

But above all these uses the electrical engineer can supply the chemist with a most efficient and convenient oxidising or reducing agent; unfortunately, however, the electrical engineer does not know what the chemist wants, and the chemist does not know what the electrician can give him.

Every week more young men begin studying to qualify as electrical engineers. Like pins, it is unknown what becomes of them. Would it not pay some of those who are sharp and inventive to take up the study of electro-metallurgy systematically, and to explore that almost untrodden field of the appli cation of the dynamo?

The PRESIDENT: It is too late to go into the discussion on Mr. Swinburne's paper to-night, but I am sure you will all join in thanking him for it. Our next meeting will be the Annual General Meeting, and will take place on Thursday, December 9th, when I hope to see a large attendance.

The meeting then adjourned.

The Fifteenth Annual General Meeting of the Society was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, December 9th, 1886—Professor D. E. HUGHES, F.R.S., President, in the chair.

The minutes of the previous meeting were read and approved.

The PRESIDENT announced that the ballot box would remain open till 8.30 p.m., and as it was probable that the scrutiny of the ballot papers might occupy some time, it was thought desirable to appoint four scrutineers instead of the usual number, two.

Mr. T. Buckney, Mr. J. Hookey, Mr. C. Hortsek, and Mr. J. N. Shoolbred were appointed Scrutineers.

The names of new candidates were announced and ordered to be suspended.

The following transfers were announced from the class of Students to that of Associates:—

Alfred L. Stocken.
A. W. Slater.

Donations to the Library were announced as having been received from E. Dawson, Esq.; Messrs. Hazell, Watson, & Viney; Latimer Clark, Past-President; Charles Mourlon, Foreign Member; Sir David Salomons, Bart., Member, and R. von Fischer Treuenfeld, Member—to all of whom a vote of thanks was accorded.

The SECRETARY then read the following Report of the Council:—

REPORT OF THE COUNCIL.

The number of elections into the Society during the year exceeds by 9 those of 1885, and comprises 6 Foreign Members, 9 Members, 66 Associates, and 33 Students, or a total of 114.

Besides these, 19 candidates have been approved for ballot at the first meeting next month.

39 Associates have been transferred to the class of Members, and 18 Students to the class of Associates.

We regret to state that by deaths we have lost 2 Foreign Members, viz., M. Julien Vinchent, Inspector-General of Public Works in Belgium, who will be remembered by many of our members as having represented that country at the International Telegraphic Conference held in London in 1879, and Don Alejandro de Bejar, Director of Spanish Telegraphs at Carthagena; 1 member, Mr. E. O. Brown, Assistant in the Chemical Department of the War Office at Woolwich Arsenal, and one of the oldest members of the Society; and 4 Associates—Mr. E. M. Oakley, an assistant of Messrs. Crompton & Co.; Mr. O. W. Smith, of the Telegraph Construction and Maintenance Company; Mr. T. Wainwright, the constructor of several of the lines of the Electric and International Telegraph Company; and Mr. J. K. Webster, of the Anglo-American Telegraph Company.

4 Foreign Members, 7 Members, and 11 Associates have resigned.

The Society continues, by the kindness and liberality of the President and Council of the Institution of Civil Engineers, to enjoy the great advantage of holding its meetings in the Lecture Hall of the Institution, and has, moreover, obtained their permission to hold additional meetings on some of the Thursday evenings intervening between the dates fixed for the ordinary sessional meetings. Of this permission, in view of the increasing number of papers offered to the Society, and the not infrequent adjournments for discussion, the Council propose to avail themselves as occasion may require.

The papers read during the session, among which must be included the President's Address, have been fewer in number than usual, but as this arose from their importance having in several instances led to adjourned discussions, the circumstance can scarcely be subject for regret.

It will be found that of these papers, a list of which follows, comparatively few have been by other than members or associates on the Council, and the number eligible for competition for the annual premiums is therefore very small.

The Council have made the following awards in respect of those read during the twelve months ending 31st May last, viz.:

The Society's Premium, value £10, to Alexander Bernstein, Foreign Member, for his paper on "Electric Lighting by Means of Low-resistance Glow Lamps."

The Paris Electrical Exhibition Premium, value £5, to Captain H. R. Sankey, R.E., Member, for his paper on "A Problem relating to the Economical Electrolytic Deposition of Copper."

The Fahie Premium, value £5, to H. Kingsford, Member, for his paper on "A Method of Localising a Fault in a Cable by Tests from one end only."

LIST OF PAPERS READ BEFORE THE SOCIETY DURING THE YEAR 1886.

Date.	Title.	Authors.
Jan. 28.	The Self-Induction of an Electric Current in Relation to the Nature and Form of its Conductor	Prof. D. E. Hughes, F.R.S., President.
Mar. 11.	Economy in Electrical Conductors	Profs. W. E. Ayrton, F.R.S., and John Perry, F.R.S., Members.
" "	Uniform Distribution of Electric Power from a Uniform Conductor	
" 25.	Electric Lighting by Means of Low-resistance Glow Lamps	Alexander Bernstein, Foreign Member.
May 13.	Long-distance Telephony	W. H. Preece, F.R.S., Past-President.
" 27.	The Telephone as a Receiving Instrument in Military Telegraphy	Capt. P. Cardew, R.E., Member.
" 27.	On a Problem relating to the Economical Electrolytic Deposition of Copper	Capt. H. R. Sankey, R.E., Member.
Nov. 11.	The Predetermination of the Characteristics of Dynamos	Gisbert Kapp, Associate.
Dec. 2.	Some Experiments on Secondary Cells	James Swinburne, Member.
" 9.	Some Magnetic Problems	Prof. Geo. Forbes, M.A., F.R.S.E., Member.

It will afford the Council great pleasure to see the younger

members of the Society more ready to contribute the results of their experience, by sending in papers on their own special subjects.

The important Committee on Electrical Nomenclature and Notation, appointed by the Society last year, having agreed as to the course to be followed in dealing with the subject, have referred the work, under certain specific heads, to a Sub-Committee, which is steadily pursuing its somewhat arduous labours; but the subject is so vast in its proportions that it must be some time before the recommendations of the General Committee are likely to assume a tangible form.

The Committee appointed to consider the proposal for the establishment of a National Standardising Laboratory for Electrical Instruments have been carefully considering the matter, and the Council hope that some practical scheme will shortly be devised for the attainment of this very desirable object.

It was confidently expected that the Electric Lighting Act (1882), which is generally believed to have proved a serious obstacle to the development of electric lighting in this country, would have been amended during the present year. Three Bills having that object were introduced in the House of Lords.

The Council, as reported at the meeting of May 13th, considered it their duty, on behalf of the Society, to present a petition to the House, praying that neither the Bill No. 3 (the Government Bill), nor any Bill for the amendment of the said Act which did not place the undertakers of electric lighting on the same footing as the undertakers of other industrial enterprises, might pass into law.

The three Bills were referred to a Committee of the House of Lords, who reported in favour of the Government Bill (Lord Houghton's), subject to certain amendments; but the Government being defeated on the division on the first amendment, the Bill was subsequently withdrawn, and the dissolution of Parliament, shortly afterwards, put an end to any further legislation for the time.

Your Council will not fail to watch any steps that may be taken in the matter during the coming session of Parliament.

The Librarian's Report, hereto appended, shows that the Library continues to receive important accessions, principally through the liberality of members and others who have written on those subjects which are of chief interest to the Society.

The Conversazione given by the President on the 29th of May last was held in the galleries of the Royal Institute of Painters in Water Colours. It was attended by a brilliant and numerous assemblage, and proved a most successful and agreeable reception.

The finances of the Society continue to be in a satisfactory condition. A further sum of £202 15s. has been invested on account of Life Compositions, and the amount of £450 has also been invested as a General Fund out of the current balance standing to the credit of the Society at the end of last year.

Having regard to the fact that the collective investments of the Society now amount to £1,863, it has been deemed advisable by the Council to appoint permanent Trustees, and the two senior Past-Presidents (Sir William Thomson and Mr. Latimer Clark), together with the Hon. Treasurer, Mr. E. Graves, have kindly consented, at the request of the Council, to act in that capacity.

LIBRARIAN'S REPORT.

4, The Sanctuary, Westminster, S.W.,
December 6*th*, 1886.

F. H. Webb, Esq.,
Secretary,
Society of Telegraph-Engineers and Electricians.

Dear Sir,

I have the pleasure to hand you, for the information of the Council, my Seventh Annual Report on the Library of the Society.

The presentations to the Library during the year have been up to the average, but there have been no special donations such as have characterised some previous years, although many of the accessions have been of considerable importance. The actual number of accessions of books and pamphlets amount to 98 presented and 22 purchased. It is most desirable that authors who are members of the Society should contribute copies of their

works to the Library. Although special letters are sent, asking for such copies, it is not always found that a successful result is attained, and copies have subsequently to be purchased. A catalogue of the recent accessions will be found appended hereto.

It is satisfactory to report that the purchases for the Library have not been so numerous as in previous years, and some saving has been effected on this account.

The total charges for bookbinding are comparatively somewhat heavy, owing to the very large number of periodicals and serials received by the Society, and which have to be bound; but the work is exceedingly well done, and I think it will be found that the total charge on Library account for this year is considerably below the amount annually voted by the Council to meet this expenditure.

The visitors to the Library during the year were somewhat less, according to the visitors' book, than in the last Report, and numbered 415. Of this number, however, only 90 were non-members.

I continue to devote considerable attention to the work in connection with the collection of the electrical specifications of patents. I presume that it is generally known that H.M.'s Commissioners of Patents publish a fortnightly journal, containing illustrated abstracts of specifications, as they are published. This journal, as I have previously reported, is presented to the Society, and, as the electrical patents are noted, it will often be found convenient to refer to these, instead of a more laborious search amongst the original specifications, which are not always complete for reference. As to the value of this collection, I might refer to the recent paper by Colonel Sir Francis Bolton, and published as a special number in the Journal of the Society. This paper was, I believe, entirely compiled from the Society's collection of specifications.

The Society's most complete collection of current periodicals remains very nearly the same as in my last Report. I append hereto a list of those we now receive.

It is my duty to again draw the attention of the Council to the want of shelf-space in the Library. A large number of books

are stowed away in parcels, to make room for current publications and those works most likely to be wanted for reference.

I am,

Dear Sir,

Faithfully yours,

A. J. FROST,

Librarian.

APPENDIX TO LIBRARIAN'S REPORT.

LIST OF PERIODICALS RECEIVED BY THE SOCIETY.

ENGLISH.

Asiatic Society of Bengal, Journal and Proceedings.
Cambridge Philosophical Society, Proceedings.
Electrical Engineer.
Electrician.
Engineer.
Engineering.
English Mechanic and World of Science.
Greenwich Magnetical and Meteorological Observations.
Illustrated Journal of Patented Inventions.
Incorporated Law Society Calendar.
Institute of Patent Agents, Transactions.
Institution of Civil Engineers, Proceedings.
Institution of Mechanical Engineers, Proceedings.
Iron and Steel Institute, Proceedings.
Journal of Science.
Military Telegraph Bulletin.
Nature.
Patents' Journal, Commissioners of.
Philosophical Magazine.
Physical Society, Proceedings.
Royal Dublin Society, Transactions and Proceedings.
Royal Engineers' Institute, Proceedings.
Royal Institution, Proceedings.
Royal Meteorological Society, Proceedings.
Royal United Service Institution, Proceedings.
Society of Arts' Journal.
Society of Engineers, Proceedings.
Telegraphic Journal and Electrical Review.
Telegraphist.
University College Calendar.

AMERICAN.

American Academy of Science and Arts, Proceedings.
Electrical Review.
Electrical World.
Electrician and Electrical Engineer
Franklin Institute, Journal of.
John Hopkins University Calendar.
Journal of the Telegraph.
Library Bulletin of Cornell University.
Ordnance Department of the United States, Notes.
Science.
Scientific American.
Smithsonian Institution Reports.
United States Patent Office, Official Gazette of.

FRENCH.

Annales Télégraphiques.
Cosmos les Mondes.
Journal de Physique.
Journal Télégraphique.
La Lumière Electrique.
L'Electricité.
L'Electricien.
Revue Internationale de l'Electricité et de ses Applications.
Société Belge d'Electriciens, Bulletin de la.
Société Française de Physique, Seances de la.
Société des Ingénieurs Civils, Mémoires.
Société Internationale des Electriciens, Bulletin de la.
Société Scientifique Industrielle de Marseille, Bulletin de la.

GERMAN.

Annalen der Physik und Chemie.
Beiblätter zu den Annalen der Physik und Chemie.
Centralblatt für Elektrotechnik.
Der Elektro Techniker.
Elektrotechnische Zeitschrift.
Electro-technischer Anzeiger.
Repertorium für Experimental-Physik für Physikalische-Tecknik.
Verhandlungen des Vereins zur Beforderung des Gewerbfleisses.
Zeitschrift für Elektrotechnik.
Zeitschrift für Instrumentkunde.

ITALIAN.

Giornale del Genio Civile.
Government Telegraph Department, Annual Report.
Il Telegrafista.

JAPAN.

Annual Report of Telegraph Department.

RUSSIAN.

Government Telegraph Department, Annual Report.

The PRESIDENT moved—"That the Report of the Council, as just read, be received and adopted, and that it be printed in the Proceedings of the Society."

Mr. J. N. SHOOLBRED, in seconding the motion, drew attention to the statement in the Librarian's Report with reference to the limited shelf-accommodation. If the Society possessed the considerable balance mentioned in the Report, better Library accommodation should not be difficult to provide.

The motion for the adoption of the Report was carried unanimously.

Mr. C. E. SPAGNOLETTI: I have very great pleasure indeed in proposing—"That the cordial thanks of the Society be presented to the President, Council, and Members of the Institution of Civil Engineers, for their kindness and liberality, in not only continuing to allow the Society to hold its ordinary fortnightly meetings in the Theatre of the Institution, but in extending that privilege to a certain number of additional evenings, as occasion may arise." We all feel much indebted to them, and appreciate their kindness, because it gives our Society a status and tone in being able to hold our meetings at an Institution like this. The privilege has recently been extended, to enable us to hold extra meetings when necessity arises.

Mr. C. H. W. BIGGS: The proposition is one which I should very much like to second. England owes a good deal to the Institution of Civil Engineers, and I think the Society of Telegraph-Engineers and Electricians owes a good deal to that body. So far as I know, a good deal of our own work has been based upon what the Institution of Civil Engineers has done, and, as one of the members of the Society, I feel that we should show our gratitude in every possible way to the Institution of Civil Engineers. I must confess that I sometimes feel sorry, when noticing certain diagrams on the wall, that the papers to which they refer did not come before our Society instead of before the Institution. I am sorry to observe this evening, for example, that there are some elaborate diagrams upon the wall, evidently illustrating a paper on some electrical subject which has been read before the Institution of Civil Engineers, and it is in furtherance of a remark made by

Professor Forbes two meetings ago, suggesting that our Vice-Presidents should now and again favour us with some of these elaborate papers, in preference to going to the older Society, which can get any amount of papers, that I make these observations. I beg leave to be allowed to second the motion.

The PRESIDENT: This is one of the motions which it gives me the greatest pleasure to put to the meeting. We cannot feel too grateful to the Institution of Civil Engineers, whose children in fact we are, for they have caused us to grow to our present importance. It is true, as Mr. Biggs has said, that some papers escape from us; and it is also true that it is partly the fault of our Vice-Presidents and Members of Council, who sometimes take papers elsewhere. I must confess, for myself, that whenever I have anything that I think worth giving, this Society always comes into my mind first. But there is another way of looking at it. It is doubtless considered by some of our senior members that, by taking papers to other societies, more opportunity is allowed for papers to be brought forward here by the younger members of the Society, whom it is desired by all of us to encourage in that direction. Therefore it is a very difficult matter to go into. Fortunately for next year we are very well off for papers, and I anticipate a brilliant session and a great future for the Society. There is not the slightest doubt that the success of our career is owing in a great measure to the kindness and liberality of the Institution of Civil Engineers.

The motion was enthusiastically carried.

Mr. W. H. PREECE: I have great pleasure in moving—"That the thanks of the Society be presented to those members who represent it abroad as local honorary secretaries and treasurers, for their kind attention to its interests." The success of this Society is not only due to the exertions which members make at home, but also, to a great extent, to the exertions made for us in other countries. We have members abroad all over the face of the earth; and our members are so numerous and so scattered that I confess myself that the mere fact of being a member of the Society of Telegraph-Engineers and Electricians is a better password to those who go abroad than freemasonry. There is no spot

on the face of the earth that I have been to where I have not been warmly received by a member of the Society; and the fact that our interests flourish abroad is due greatly to the energy and assiduity with which our local honorary secretaries and treasurers attend to their duties. The list of those gentlemen contains names well known for the work they have done in furthering telegraphy and electricity, such as Dr. Werner Siemens in Germany; Mr. Charles Todd in South Australia, who is the head of the Meteorological Department and of the Telegraph and Postal Department; Mr. McGowan in Victoria; Mr. John Aylmer in Paris, who is known to every one of us almost as a personal friend; and so on, if we go to Canada, New South Wales, India, or to any other country or English colony, we come across names that are familiar to us; and it is to those gentlemen that I propose that the thanks of the Society be presented.

The PRESIDENT: For my own part, I have seen most of the local honorary secretaries abroad, and know them. They are men of the highest capabilities, many of them holding high official positions; and all our foreign, Indian, and colonial success is entirely due to the aid of those gentlemen: it is very much due to them that we are an international body instead of simply a national one.

Mr. C. H. B. PATEY: I can fully confirm what the President and Mr. Preece have said as to the very great help that the Society receives from the local honorary secretaries, and would also testify to the very pleasant manner in which any member of the telegraph world is received abroad. I have been on business for the Government to most of the capitals of Europe, and I can assure you that the kindness and courtesy shown, and the information which is willingly given, from the highest to the lowest, especially by those introduced as members or officials of the Government, is a fact that one brings back to this country with pleasure. One only hopes that when any members of kindred societies from abroad come here they will be able to take back a similar record of our readiness to give them information, and of the courtesy and kindness which they received while here.

I have very great pleasure, indeed, in seconding the motion which has been made.

Carried unanimously.

Mr. A. W. HEAVISIDE: I beg to move—"That the thanks of the Society are due Mr. Edward Graves, V.P., Honorary Treasurer, for his continued watchfulness over the financial interests of the Society." I am sure that there are many gentlemen present besides myself who have a personal knowledge of Mr. Graves' ability in finance, and I feel sure that the interests of the Society are quite safe in the hands of such an honorary treasurer.

Mr. J. SWINBURNE seconded the motion.

The PRESIDENT: No one knows except the members of the Council the care and attention with which Mr. Graves has so kindly taken charge of our finances for so many years. Nothing involving expenditure is ever done without first consulting him, and if he says such a thing must not be done we never doubt his opinion, and he has always kept us so straight that there is now a nice balance at the bankers; and I am sure that we respect him none the less because he will not let us go beyond our means.

The motion was carried unanimously.

Mr. EDWARD GRAVES was glad that the position of the Society was so much better than it was a few years since. He could not take to himself any considerable credit for the fact, for it was really because members as a rule paid their subscriptions at the present time, while they did not do so ten years ago. He hoped the reformation in that respect would continue, and he thanked the members for the vote.

Mr. GRAVES: I beg to move—"That the thanks of the Society be presented to Mr. J. Wagstaff Blundell and to Mr. Fred. C. Danvers, for their kind services as Auditors." A mistake had hitherto been made, in not describing their office as "honorary," but in the future that will be corrected, as their services to the Society are rendered quite gratuitously.

Mr. H. T. GOODENOUGH seconded the proposition, which was carried unanimously.

Mr. LATIMER CLARK: I have been permitted to move a vote

of thanks to our honorary solicitors for their kind attention to our interests. I am very pleased that it should have fallen to my lot to move this vote of thanks, because perhaps I know more of those gentlemen than many of our present members. I shall perhaps surprise you by saying that they have been connected with the electric telegraph very much longer than most of those connected with this Society. I have myself known them for some thirty-five years in that connection. The firm of Wilsons & Bristow were originally the solicitors of Sir William Fothergill Cooke, and it was they who fought his battles throughout, not only in his differences with Sir Charles Wheatstone, but also in the agreements he had to make with the various railway companies in those early days. From that they became the solicitors of the Electric Telegraph Company, and Mr. George L. Bristow, who is the gentleman who gives special personal attention to our interests, was at that date a very active member indeed of the firm, especially of the telegraphic branch of the firm. It has not fallen to our lot, fortunately, to be involved in any lawsuits or proceedings of that nature, but Mr. Bristow has given a great deal of attention to us, and especially in connection with our incorporation. I can assure you, from personal knowledge, that when anything had to be done by them, it was done as carefully and as fully as if they were paid the highest charges they could have made.

Dr. M. J. JACKSON seconded the motion, which was heartily carried.

The PRESIDENT: We now come to the ordinary business of the meeting, which commences with the discussion on Mr. Swinburne's paper on "Secondary Cells."

Mr. Crompton. Mr. R. E. CROMPTON: I think that, in a sense, Mr. Swinburne's paper is one of extreme value to those who are working on this subject. It is true that in one sense the paper may be considered as a record of a series of failures; but these failures are most instructive, and we may say that Mr. Swinburne has buoyed the channel for us, and has prevented us going on to shoals and difficult places which we otherwise would have done,

Mr. Crompton.

and would have spent much of our time and money in directions which he has shown to be entirely useless and inoperative. The subject is an extremely interesting one to me. I have for the last two years been studying it, and I find it an excessively difficult one to study; the results obtained are so puzzling, as this paper itself shows. So many questions have to be considered that, when we get a failure, it is not easy to put down the correct cause at once; generally three or four causes offer themselves from which to choose. I think I can best serve the discussion by just touching on one or two of the points which I have investigated myself. First, as to the experiments with cells of hair lead. I agree with him that the failure of the very large plates, one inch thick, made by Mr. Cookson, was entirely due to local action, or rather more correctly, I should say, three parts due to local action, and the remainder due to want of continuity of the active substance. I do not think lead can be taken and pressed into a plate in any such manner that the continuity is perfect sideways of the filaments. It may appear to be so even when examined under the microscope, but the electrolyte very soon finds out the lines where they have been joined, follows them out and separates them into the original filamentous state, and then the only good continuity is through the ends of the filaments, which is of course very small, and it is easy to see that four-fifths of the active material is useless, because it is not connected electrically with the electrode itself. The next point is Mr. Swinburne's explanation, on page 2, of the action of these cells. I think that what he has told us about Messrs. Gladstone and Tribe's book is not all printed, that it was added after the paper was printed; but if I understand him right, he found fault with Messrs. Gladstone and Tribe for their complex method of explanation of the action that takes place in a secondary cell. He said there were always two or three processes to be explained, and that it was very much like a man going to the top of a house and coming down again in order to reach the second floor, instead of going there direct. Does not his own explanation savour very much of the same quality? He states that wherever lead is in contact with

r.
rompton.

peroxide there is a sulphate formed at that point of contact; and then afterwards he says the sulphate is reduced, and afterwards there is fresh sulphate formed. Well, I do not understand where all these "afterwards" come in. It is a continuous process that he is describing, and not an alternate charging and discharging. He says that formation goes on during process of continuous charge. Well, I fail to understand how he gets this continuous process which results in the lead backing being continually attacked, and an increased film of the peroxide being formed. I do not think any satisfactory explanation has been given of this phenomenon, because I do not believe it exists. I do not think that charging in one direction for any time will form a deep film; there must be some cessation of the charge, or some discharge. I think probably cessation is sufficient, but formation is very much quicker if discharge is made alternately with charge; and my own experience leads me to suppose that, to make the formation as rapidly as possible, the discharge should be carried right down, and that the cells should be completely emptied. I believe that every time the cell is completely emptied there is a better chance of attacking the lead. I think that when we are working in this subject a clear insight should be given of the action of formation. I myself am always puzzled to know at what point action commences. Imagine a plain lead plate has a film of peroxide on it. At what point does the action commence? Does it commence on the surface of the peroxide next to the electrolyte, or does it commence at the point of contact of the peroxide and of the lead? At what point does the change into sulphate commence? My own impression is that there is no hard and fast line, but, in fact, that these two surfaces fade off one into the other without any sharp line of demarcation: there is a sort of marshy margin throughout the whole of which the electrical action goes on.

Turning now to some of the practical points in the paper, I notice that Mr. Swinburne says what a troublesome thing spray from these batteries is. It is needless to say that that can be stopped by putting covers on the cells. There is no difficulty in

doing so with any material that is not attacked, but the method employed, particularly for large cells, at Vienna has been to make tight-fitting lead covers, and to bring the terminals through these covers through india-rubber tubes, and in that way the cell is air-tight, but there can be a small hole to relieve gas pressure: no spray is given off, and bright machinery can be kept comparatively near to the cells without being attacked at all. Mr. Crompton.

I wish to call attention to Mr. Swinburne's figures as to the comparative bulk of peroxide of lead, red lead, litharge, and lead sulphate. Those figures are very instructive, if they are correctly shown, and if the lead sulphate is to peroxide as 297 is to 160, it of course points out very clearly the cause of the buckling and twisting of the plates, which has been one of the greatest difficulties we have had to meet. At one time a great many of my experiments were made with porous lead plates,—plates which had been cast in such a manner that they crystallised in cooling,—and when they were drawn into thin plates the whole of the material became pervious to the electrolyte. A plate of that kind six inches square would grow to eight inches square, and at one time we thought that that growth was a very fine thing: we thought that it really meant that we were making the plate more and more active, and that we were getting more and more useful material; but recent experience has led me to believe that that idea was wrong, and that as more active material was obtained continuity decreased, and that the greater part of heavily grown plates became useless. The best plates that I have known have been those that have grown least, and very magnificent results both of heavy discharges and great capacity have come from plates which, after having been formed for a year or a year and a half, have not grown more than from 6 inches square to 6¼ inches square: and this is very comforting to us, because it is evident that if a plate grows rapidly it loses mechanical strength, and is quite unfit for rough work at all, such as driving tramcars, and things of that sort; whereas it is proved that plates will get sufficient formation without any inordinate growth, without stretching the fine filaments of lead

Mr. Crompton.

which join the whole fabric together to such an extent that there is no longer any electrical continuity.

Mr. Evershed.

Mr. S. EVERSHED: Mr. Swinburne's paper gives me a convenient opportunity of bringing before the Society a rather curious phenomenon which I observed about two years since, when working with small secondary cells. I had been forming a set of small Planté cells, and on one occasion, on cutting off the charging current, I noticed a rush of large bubbles to the surface from the whole of the cells simultaneously. Of course I thought I had shaken the cells, and I put on a very small current, and on carefully breaking the circuit (so as not to shake the cells), and observing the cells at the same time, I saw the large bubbles which had formed on the anodes rush to the surface instantly. I was able to repeat the experiment several times, and as I was working with Mr. Swinburne, I called his attention to it. We did not at the time go into the theory of the thing, and it has been put on one side. Quite recently I have made a rough experiment to ascertain, if possible, the cause of the rising of the bubbles. I had an idea that the surface-tension of gas bubbles might be diminished under the electrical action of the cell, and that, if I could collect a large bubble the surface of which could be easily altered on starting or stopping of the current, I should observe some alteration in its shape. However, nothing of the kind occurred, although I varied the conditions of current density, etc., as far as possible: neither oxygen nor hydrogen bubbles seemed to alter in shape in the least. I should be very glad to hear if some one else has observed this phenomenon, because, as far as my rough experiments have gone, I have not even been able to reproduce the conditions which evidently obtained in my experiments two years ago.

The President.

The PRESIDENT: The subject which we are discussing to-night is one of great importance: it could not be exhaustively discussed, in fact, in two or three nights, but I have three more speakers on the list who wish to be heard. There is also Professor Forbes' paper, which we hope to be able to hear, and therefore I must ask speakers to be as brief as possible, to give Mr. Swinburne time to reply.

Mr. SYDNEY F. WALKER: I will only make a very few remarks, as the time is short. I think we all are very much indebted to Mr. Swinburne for what he has said, and also to Mr. Crompton for his remarks. It is quite as important for us to know what we cannot do as to know what we can do, as if we know all we cannot do there is not very much left; and the subject is a most difficult one, because the electro-chemical and electro-mechanical requirements are in opposition. If you are to have a large current capacity, a big charge that is to say, from a comparatively small battery, apparently you want a large quantity of active material, which must be in a certain spongy state; and practically it amounts to this, that when you have a perfect plate electro-chemically it is useless, because it will not hold together. That is, as far as I can gather, the question, and apparently the experiments that have gone forward, divide themselves distinctly into two kinds—those in which a plate is plugged with active material, and those in which the plate is formed. Those who have experimented with the kind in which the plate is formed, apparently have endeavoured to divide up the plate as much as possible into very thin laminations in hair lead, and in the form which Mr. Crompton has referred to; but apparently the result is that, when they have got their perfect form, it is useless, because it is so rotten, and requires a backing of some kind. I imagine that with those in which the plate is plugged (I have not had very much experience with them) there must be a very great risk of the material falling out, owing to the unequal bulk which it occupies. Assuming Mr. Swinburne's figures to be correct, if you plug a hole with peroxide of lead, and it expands or contracts, whichever way you take it, there is great risk of its falling out and short-circuiting, and so on. Therefore, as far as all that I can read, and can learn from experiments that I have made, the direction which we have to go in appears to be on Planté's old lines, only to make the cells big enough; but of course their size is limited when they have to be portable. There are many cases—country house lighting, private lighting, etc.—for which secondary cells are a practical necessity, and in which it will not matter how heavy the cells are; but for Mr. Walker.

portable work some sacrifice will have to be faced. Apparently you cannot have long life and high charge in a small weight and compass. One of the great, almost the greatest difficulty, so far as my experience goes, in the use of secondary cells is the uncertainty of individual cells: you never know exactly when a cell is going to break down, and it does not end with the loss of its own electro-motive force. It is not a dead horse, but it becomes a horse pulling against you: you have to work through its resistance, and the working current going through it, as Sir David Salomons has pointed out in his pamphlet, sets up an opposing electro-motive force, so that practically it takes two cells to neutralise it; and I think, until we can get over this, and we can have cells which will not be liable at uncertain times to break down in this way, we shall not be safe, if I may say so, in using secondary cells, except in special cases where there is skilled labour always at hand.

Professor W. E. AYRTON: I have had very little to do with the formation of cells since the early days of the Faure accumulator, about 1881-82; although I have have a good deal of experience since in the use of secondary cells. Speaking as a user, I have found that cells which are sent out ready formed, such as those supplied by the Electrical Power Storage Company, are much more convenient for users than those which are sent out with directions telling the buyer how to form the cells, which takes several weeks. In the ready-formed cells of the Electrical Power Storage Company, the positive plate—the plate by which the current enters in charging, and by which the current leaves in discharging—has in its holes minium, Pb_3O_4, while litharge, or PbO, is used for the negative plate. The different way in which plates are made consists in using a different oxide of lead for the positive plate to what is used for the negative plate, and that, I believe, is one of the great recent improvements. In the early days of the Faure accumulator, minium was used for both positive and negative plates. Also the modern plates are formed separately, but we will not go into that. In the early days of the Faure accumulator we were under the impression that lead sulphate was the great bugbear, and was to be got rid of by

using sulphuric acid. As far as I know, Dr. Frankland was the first to show that the lead sulphate was the most important thing in the cell, and I understand from the best chemists that the action in the accumulator in charging is the breaking up of lead sulphate $PbSO_4$ into PbO_2 which is deposited on the positive plate, and Pb which is deposited on the negative plate, with a liberation of sulphuric acid, H_2SO_4; while the action in discharging is the re-forming of the lead sulphate $PbSO_4$. If that is the action of charging and discharging, why do we go through this roundabout way of getting the lead sulphate when it is lead sulphate which is decomposed in charging by the liberation of sulphuric acid, and which is reproduced in discharging? Might it not be possible to accelerate the formation of an accumulator by putting a certain amount of lead sulphate in it to start with? Professor Ayrton.

Mr. BERNARD DRAKE: My experience has been mostly confined to one form of cell, which I have endeavoured to render a commercial success, and I have had little time for experimenting with batteries on entirely different lines. Mr. Swinburne states that if lead and peroxide of lead are electrically connected, and any of the surface of the lead is exposed to the acid, that part of the surface is attacked, and a thin film of sulphate is formed, which protects the surface from further corrosion. This was the old idea, which I believe we were the first to disprove. If sulphate is allowed to collect, the grid will be soon destroyed throughout. The protecting coat is one of dense peroxide and not sulphate. The table of volumes occupied by lead in different forms is most instructive, and clearly bears out our statement made before the British Association, that the formation of sulphate was the main cause of buckling. It is clear that if the pure lead grid is converted into sulphate, an expansion takes place, and the plate must either "grow" or buckle. The destruction of the flannel referred to might have been caused by the strong sulphuric acid formed during charge. The flannel would prevent this from mixing with the remainder of the electrolyte, and the flannel would therefore be destroyed. Probably, also, the cells would give a bad result, as we found that Mr. Drake.

Drake. with 1,400 acid in contact with the plates, they would hold little or no charge, and the protecting coat was destroyed. A number of experiments were made by us when with the Storage Company, with matting fibre, asbestos, and other materials as insulators, but the grid was soon rotted through in regular work, I presume from the above cause.

We tried a number of experiments with zinc used in connection with peroxide plates. This combination was patented by Dr. Lodge some four years back. The results were good for a short time, but in practice it was found impossible to prevent the formation of lead trees. I should not recommend any one to put oil or paraffine on the top of the acid, as it has been found liable to injure the plates.

Mr. Swinburne's paper will be extremely valuable to any one who is experimenting with new forms of batteries.

iburne. Mr. J. SWINBURNE, in reply, said: Mr. Crompton appears to agree with me so far as to the Cookson cells, but I do not think we quite understand each other. Mr. Crompton has been working with cells with very much less surface than the Cookson, and has reversed in forming. In the Cookson cells reversal in forming was not necessary, because the surface is so enormous that with very slight local action the whole of the charge put in during the day was run down. Eventually, on cutting these cells open after about five months, we found that the hairs of lead were almost entirely converted into peroxide of lead; there were little hairs of lead peroxide with a very fine filament of lead in the centre of each. There appeared to be no want of continuity; in fact, if there had been want of continuity, gas would have been given off.

As to my remarks on Messrs. Gladstone and Tribe's work, I think the best thing to do is to insert them in the paper.

A question was asked by Professor Ayrton as to why people do not begin with lead sulphate instead of oxides. In the first place, if a plate were filled with lead sulphate, it would be filled with such a bulky material that, when oxidised into peroxide on one side, and reduced to lead on the other, the coatings would be so loose that they would tumble out. I think that why minium was used in the early days was that people then thought that the

action of a battery depended upon the peroxide descending to PbO, and not to its being converted into sulphate. If minium is mixed with sulphuric acid, lead peroxide and lead sulphate are formed. If the minium is made into a paste with water instead of with acid, and spread into the holes in the support, and the acid then allowed to soak in, the sulphate formed seems to crystallise in such a way as to make a very hard coating. That is probably another reason for the use of minium. Mr. Swinburne.

I cannot say anything about what Mr. Drake has said as to the flannel. I do not really know whether its destruction is due to the oxidising agent or to the sulphuric acid; but peroxide of lead is one of those substances that act on nearly every organic substance. With very strong sulphuric acid, say 1·7, I should think that most probably the thin film of peroxide, which would otherwise protect the plate, is not formed, but that a sulphate is formed in a loose condition, which tumbles off and leaves more plate exposed. I think that Mr. Crompton and Mr. Drake have misunderstood my remarks on forming. I maintain that, when you form a plate and begin to charge it, you first get a film of peroxide; then, if you leave the plate alone and do not go on charging it, the acid penetrates the oxide to a slight extent, and, getting at the lead, forms a film of sulphate of lead. When you pass electricity through again, that is oxidised, but if you leave it there it protects it so far; but if this action goes on over and over again, the coating of peroxide gets closer and closer, and protects the lead. Hence it is the peroxide which protects the lead finally, though at first the local action is stopped by the small film of sulphate. Thus the lead can be protected by the sulphate or by the peroxide, though when a plate is attacked it is converted into one of these. They protect it simply by preventing the acid from coming in contact with lead and lead peroxide electrically connected. Whenever lead and lead peroxide in electrical connection come in contact with acid, a current passes and sulphate of lead is formed.

The absence of fall of electro-motive force when zinc is used is instructive in one way, because it may show that the fall of electro-motive force in an ordinary cell, such as the Faure or

Mr. Swinburne. thickly formed Planté, is due to the internal resistance in the coating, due to weakening of acid, or blocking of the little passages and interstices by sulphate of lead.

I do not think that strong sulphuric acid in a secondary battery is quite similar in action to nitric acid in a Grove cell. Strong sulphuric acid dissolves a little more sulphate than weak sulphuric acid, and I think that when the sulphate was formed on Mr. Drake's plate it was partly dissolved, and was therefore loose and would not stick. Mr. Crompton has pointed out to me the curious phenomenon of a pink liquid appearing in the cell, I think when beginning to reverse.

Mr. CROMPTON: Yes.

Mr. SWINBURNE: I took some trouble in investigating this, and find that if peroxide of lead is shaken up with diluted oil of vitriol for some weeks, a liquid like a solution of potassium permanganate is produced. I found this solution contains iron persulphate, and it is likely the red colour is due to free ferric acid. The colour is discharged by addition of an iron protosalt, or by boiling, or by filter paper. Pink crystals are sometimes formed in distilling oil of vitriol. The peroxide shaken in the acid smelled strongly of ozone.

The President. The PRESIDENT: We have had a most interesting paper by Mr. Swinburne, which time prevents my going into myself, and which time also, unfortunately, prevents being discussed to the extent it merits by others, and I am sure you will all join me in according our thanks to him for it.

A vote of thanks was heartily accorded to Mr. Swinburne for his paper.

The PRESIDENT: We are at the end of the session, and this is one of those occasions on which it is impossible to estimate beforehand what time will be available for a second paper, and to meet this difficulty Professor Forbes has kindly consented to go as far as time will allow in bringing before us "Some Magnetic Problems."

Professor G. FORBES: It is very good of our President to llude to the subject of my communication in the way he has

done. I had intended to begin by explaining that as the papers which the Secretary has in his hands are of considerable length and will probably give rise to prolonged discussion, the President asked me if I would undertake to give any notes which might occupy a longer or a shorter time according as might be wanted, or not give any at all if time did not permit. I happened to have some notes lying by me which I thought I might communicate to the Society, and I agreed to do so. I have, however, since then felt very doubtful whether they are suitable to the Society, which, of course, deals to a great extent in the technical, rather than the purely scientific aspect of electricity.

I am going to bring before you some suggestions which to many of you may perhaps be known, but I do not wish you to think for one moment that I claim the slightest credit for any originality of suggestion in these; in fact, I deserve blame, rather than credit, for bringing the matter forward in the way I am about to do, because no such matter ought to be brought before you, as a general rule, without experimental verifications; and the only reason why I do it is, that I foresee that, before I can get my experimental verifications out, the time will be protracted, and I should be very glad if other members who have more time and facilities would undertake them, and to them would be the credit of the work done. I say this because it is likely that others besides myself have gone quite as far as I have gone in the matter, and probably much further, and they simply withhold it from the proper feeling that they ought not to bring such a matter forward without experimental verification.

I have no doubt that to many people it has occurred, in thinking over the phenomena of electro-magnetism, especially when they see how all the different phenomena of electro-magnetism which we know may be deduced directly from Œrsted's experiment by consistent reasoning on the laws of energy, whether the labours of Œrsted, Faraday, Ampère, and Sturgeon really complete the whole field of electro-magnetic phenomena; and, as we think over the subject, we shall certainly see that there is one line in which the phenomena

of electro-magnetism have not been fully developed by experiment. All these suggestions which I am going to make are founded upon one idea—upon the idea of what happens during the existence of what I may call a magnetic current. If we have a long iron wire, and if we put one end of it into a coil through which we send an electric current, the magnetism is conducted from point to point along the wire, and during that moment of rearrangement of the magnetism there is what may be called a magnetic current travelling along the wire. The question arises whether there are any properties to be discovered in this magnetic current, or in the iron which is carrying this magnetic current, of a character like those belonging to conductors of the electric current, and so on. I have no doubt that there are several gentlemen in this room who know quite as well as I do that there are effects produced during the time when such a magnetic current is travelling along an iron conductor. I will give you an idea which will bring this home to you very readily. Suppose you take a ring of iron and wind around it a coil of insulated wire so as to have the appearance of a Gramme ring, with a break in the copper conductor so as to permit a current circulating round it continuously in one direction,—at the moment when the current is put on in the one direction, or at the moment when the current is reversed, a magnetic current of the type of which I have been speaking is temporarily established in the iron ring. We know that at that moment, an electro-motive force is created along certain lines of induction passing through the axis of the ring and returning round by the outside. We know that, if a metallic circuit goes along one of those lines of induction, the electro-motive force will create a current through that conductor. But we know of other things which an electro-motive force will do besides creating a current in a conductor. If there be no conductor in a space which is acted upon by an electro-motive force, but only an insulating material, we know that the insulating material is put into a state of strain; and if in such a space where an electro-motive force exists there be a positively or negatively charged body, we know that it is moved along the direction in which the electro-motive force is acting: consequently, we have

arrived at this conclusion, that, at the moment when there is a magnetic current travelling round this ring, a charged electric body placed in the axis will be moved along the axis of the ring in one direction or the other, according as the body is charged positively or negatively. This is the first experiment which it is desirable to see undertaken. We wish to exaggerate this to a considerable extent, to make the effect as large as possible, and then try and get the actual effect observed of the influence of a magnetic current upon a charged electric body. We have considerable difficulty in making any experiment upon these magnetic currents which undoubtedly do exist, but they travel through such a short distance in iron, if the iron is in the form of a wire, that it is very difficult to make experiments upon it. I believe that experiments have been made by our President upon the transmission of such a magnetic current through iron wires, and it was partly in the hope that I might draw out something from him in relation to his experiments that I thought of bringing this subject before you. But the distance over which such a magnetic current travels under ordinary circumstances is remarkably limited.

Now with regard to the experiment which I wish to have made. These are facts, these are not speculations. Of course we perfectly well know the truth of these facts, and we can actually measure what will be the attraction of any charged body in the centre of the ring at the moment when the magnetising force is applied, and I have pointed out what the effect will be upon a certain supposition. I would suggest that, in the first idea of the experiment, we should employ a Gramme ring of great length parallel to its axis, with the wire cut, of course, so that a current can be sent continuously round the copper conductor; near the centre of that ring I would suspend, in one arm of a balance, the electrified body, balance it carefully by weights, and then suddenly send a current in one direction round the ring of the armature and reverse the current, when no doubt a sensible deflection of the suspended electrified body would be seen. I will not go into the calculation, but I will just tell you the result. If the

radius of the body which is electrified is 1 centimètre, and if the potential at which it is charged is 50,000 volts, and the iron of the ring about 3 centimètres thick, then the momentum which could be given to the scale-pan would be equivalent to taking off one-tenth of a milligramme and lifting it off from the scale-pan during 10 seconds. Now we know perfectly well that our balances are sensitive enough to indicate that perfectly easily, therefore that method would actually suffice for the moment. But I should, of course, use a much more sensitive way than that. The plan which I would suggest [*proceeding to the board*] for the experiment would be a modification of the electrometer. Looking downwards on the electrified arrangement, it would consist of two suspended conducting segments of circles connected by an insulating material, and fastened outside them would be other segments or a complete circle of metal. This, then, would act as a condenser, very much like a Leyden jar, and one would be able to charge these two suspended segments with a very great quantity of opposite kinds of electricity. This arrangement would be suspended from the centre by a fibre of silk. Then the Gramme ring would surround all this with its axis horizontal. I would send a beam of light along the axis to a mirror, and at the moment of magnetising and reversing I should see the deflection: one of the segments being charged positively and the other negatively, the positive would tend to move in the one direction along the axis, and the negative in the other direction along the axis, and there would be a slight rotation which would be observable by means of the mirror.

There is a great deal more: this is merely an introduction to the subject. You will see that there is a great analogy to the way in which Faraday's and Ampère's discoveries can be worked out from Œrsted's original discovery; and, by studying the development that may come of the magnetic current, we shall find that there is an almost complete analogy between the mutual action of a magnetic current and a charged electrified body on the one hand and of an electric current and a magnetic pole on the other—that almost everything which takes place with electric currents and magnetic poles similarly takes place

between the magnetic current in iron and an electrically-charged body, and that the mathematics of the two problems are identical. You might imagine two iron wires going along parallel to each other, and you might ask whether, when a magnetic current is passing through each of those two wires, there would be any attraction or repulsion between them. The answer to that is exactly the same as in the case of electric currents. If they are travelling in the same direction there will be an attraction between the two iron wires, if they are in opposite directions there will be repulsion. I will not go into the full principles of this, but I will illustrate it in a way which, I think, will show you that it is right. We have seen that an iron ring, like the one I hold in my hand, when a magnetic current is passing through it, creates an electro-motive force in its neighbourhood, so that it will attract, we will suppose, a positively charged body held above it. Now we know that action and reaction are equal and opposite, therefore we know that when the charged body is held above the ring, then at the moment of sending the magnetic current through the ring it must be attracted up towards the charged body—in other words, the presence of the electric field made by the charged body causes the conductor carrying the magnetic current to move parallel to the lines of the electro-motive force. Now what does that lead us to? Suppose we have two rings placed one above the other, we know that if the magnetic current is created in one of these rings it creates an electro-motive force in its neighbourhood, and we know that the other ring itself is creating an electro-motive force, and, when subjected to the electro-motive force produced by the first, is acted upon by it so as to approach it: thus we see that with these two rings, if the magnetic current is going in the same direction in both simultaneously, there will be a mutual approach of the one towards the other. It comes also readily out that if you have them in reverse directions the opposite will take place. You easily see then that the same thing will occur when I extend these rings out to an indefinite size. I should then be reaching the case where I have two parallel wires running side by side, and we have arrived at the conclusion that when magnetic currents are

travelling in the same direction along these two iron wires there is an attraction, and when going in opposite directions there is repulsion, exactly analogous to the Ampèrean law of current. Let us consider the question a little further. We have got two wires, free in space, parallel to each other; a magnetic current travels through the two of them, and there is motion due to attraction. That motion represents a certain amount of energy; a certain amount of energy must be absorbed somewhere in order to cause that amount of work represented by the attraction. Where are we to get that amount of energy from? where does it come from? Clearly it comes from the magnetic current—that is to say, the magnetic current is weakened by the passage of the other magnetic current parallel to it. In other words, the approach of one magnetic current towards the other induces a counter magnetic force in that other, tending to diminish the strength of the magnetic current. We may say that a magneto-electro-motive force (if you like to call it so) is created which tends to set up a magnetic current in the opposite direction. That leads to the fact that if I have a current travelling through one wire and approaching another iron wire, it induces in that other iron wire a magnetic current in the opposite direction to the inducing magnetic current, another exactly analogous thing to the induction of electric currents in neighbouring wires by their approach or recession. I need not go on and complete that by pointing out that a recession of one wire from the other will create a magnetic current in the same direction, which of course is the case, or that the sudden making and breaking of the current in one wire, without approach, will suffice to create one in the opposite direction in the other.

I think I cannot go more fully into these questions without going *very* fully into them, and I quite foresee the full criticism that every one is entitled to make, that it is not justifiable to bring forward such suggestions without experimental verification; and it is perfectly true, I know, that there must be plenty of other people who have been thinking out these things, and who will wait to announce them until they can produce experimental verification. I only hope that my remarks will

lead to the easy verification of the one experiment that I have suggested. The instrument which I drew on the board is one easy of completion and certain of success; the others are very much more difficult, and it is quite problematical whether at present we have instruments of sufficient delicacy to detect the effects.

The PRESIDENT: We are very much obliged to Professor Forbes for his kindness in keeping us interested and instructed pending the report of the Scrutineers, who appear to be having a heavy task. The President.

Mr. J. SWINBURNE: I perhaps did not quite gather the practical application of Professor Forbes' suggestion, but it seems to me to be a method for measuring a varying current when there is an electro-motive force in circuit. That I think has never been done yet, and I think there is no known way of doing it. Mr. Swinburne.

I do not at all see how Professor Forbes proposes to do this; as far as I understand his apparatus, he would determine $\int e^2 \frac{d\,c}{d\,t}\,d\,t$, e being the electro-motive force, and c the current. What is wanted is the average current, $\int c\,d\,t$, and the average electro-motive force, $\int e\,d\,t$. Of course an electro-dynamometer integrates the square of the current through it, $\int c^2\,d\,t$, and gives a virtual current, and in practice this virtual current is what is wanted, as when multiplied by the virtual electro-motive force it gives the actual power spent, provided there is no local electro-motive force in that part of the circuit. If there is local electro-motive force the result is wrong; but then the product of the real integrated current and electro-motive force does not give the power either. In practice the power is always what is wanted, and this can be measured in the usual way by using an electro-dynamometer with a thick and a thin coil, the thin coil being so coupled with an external resistance without self-induction as to have a current at any moment proportional to the electro-motive force. Such an instrument always reads the power spent accurately; though of course an electrometer used according to Ayrton and Perry's modification of Joubert's arrangement is better.

Mr. Biggs. Mr. C. H. W. Biggs suggested that the great similarity between magnetic and electric phenomena seemed to suggest they were one and the same, and that they might be studied as such.

Mr. Snell. Mr. W. H. Snell: I am quite sure that all those who may be working with alternating currents will very warmly welcome any additional facilities for measuring the work done in such circuits. We already possess, however, a means of calculating with tolerable accuracy the work done by an alternating current, in terms of the electro-motive force, the periodic time, and the resistance and the coefficient of self-induction of the circuit. Of these terms, the first three can be measured at one observation with sufficient accuracy for practical purposes; but the determination of the coefficient of self-induction is a matter of greater difficulty. I have found in practice that the method first proposed by Mr. Blakesley some two years ago is very convenient. This method depends upon the use of a Siemens dynamometer in which the fixed and movable coils are furnished with separate terminals, so that a current can be sent through either coil separately, or through both together as usual. The method is best suited for use with transformers: it is in any case necessary that the circuit whose coefficient of self-induction is to be measured be either a primary or a secondary circuit. We first measure separately the primary and the induced current in the usual way, and then, disconnecting the coils of the dynamometer, we put one in the primary, and the other in the secondary circuit. We then obtain a deflection which Mr. Blakesley calls the "force reading." From these three readings and the known value of the periodic time, we at once calculate the value of the coefficient of self-induction of the secondary circuit, and also that of the mutual induction between the two circuits.

Mr. Preece. Mr. W. H. Preece: Professor Forbes has offered to us remarks that are very pregnant, and that will be the means of directing a good many minds to wander in regions into which the more practical man does not often venture. He has seen, more with the mind of a philosopher than of the engineer, certain mutual results going on between electricity and magnetism that lead us

still further to see the intimacy existing between the two, and Mr. Preece. to bring about what I have always held must sooner or later be brought about, that which Mr. Biggs has suggested, the actual identity between electricity and magnetism. It is a remarkable thing that there is scarcely, without exception, a single phenomenon of electricity that we deal with, either in its practical application or in its experimental development, that we do not find the presence of these two agencies involved together, and always in such a mutual relation that it is almost impossible to separate the two. Professor Forbes has, in that way that we are all so familiar with, and that we all admire so much, given us perhaps a better idea of a magnetic current, by the analogue of an electric current, than we have had before. Most of us who have thought on this subject must have felt at times that there must be in magnetic phenomena a magnetic flow something like that of electricity. We know in all inductive effects, whether they be electrostatic or electro-magnetic, that we have either motion itself or that which tends to produce motion. Now, while we are all perfectly familiar with the term electro-motive force, we are not all of us familiar with what Professor Forbes has called "magneto-motive" force, and yet there must be present in these formulæ not only electro-motive, but magneto-motive forces. No man who has existed was able to peer into this undiscovered country with such power as Faraday, and there is no one who has given electricians such tools with which to investigate this unknown region as he. The conception of lines of force was to him perfectly ideal, as well as to all old writers on electrical subjects, whether philosophical or mathematical; but now, with the intensely practical applications of electricity, those notions of Faraday of ideal lines of force are coming to us absolutely as realities; and the electrician who thinks theoretically over the subject can picture that which goes on in the neighbourhood of a dynamo machine, or in the neighbourhood of a wire, as something that can not only be depicted on the blackboard or on paper, but something that really exists in nature as lines of force. Professor Forbes himself, in describing the probable action that takes place between a magneto current and the attraction or the repulsion of

Mr. Preece. an electrified mass, sees in his mind's eye that there must be these lines of force existing in some real form to produce this real effect; and the most striking features, to my mind, of the suggestions made by him are the means by which we may detect the action that exists between a pure magneto effect, like his magnetic current, and the attraction or repulsion of a body charged electrically.

I believe that Professor Ayrton and Professor Perry have attacked this subject from the reverse point of view, and have shown that it is possible to account for other phenomena by the reaction between a charge of electricity on the surface of a sphere rapidly rotating and a magnet in the centre of that sphere; and although not quite in the same direction as Professor Forbes has suggested in his experiments, still it is a connecting link that will ultimately bring together these two forces into one continuous whole. The lines of force in an electric field are exactly at right angles to the lines of force in a magnetic field; and since it is quite impossible to conceive action at a distance, whenever we have action it must be due to motion, either in the form of waves or in some other form, in the medium conveying this force: so that when we have a field such as Professor Forbes has suggested, it is not difficult to see that we may have one component of the motion in one direction producing lines of electric force, and another component of the same motion at right angles to it producing lines of magnetic force. I am bound to confess that I have listened to Professor Forbes' remarks with very great interest, because the connection between these two things is always more or less evident; and I do hope that the seed that he has thrown down will fall on fruitful ground, and that we may have in the course of next session some results carried on in the direction that he has suggested which will still further increase our knowledge on this very complicated subject.

Mr. Kapp. Mr. GISBERT KAPP: The subject brought before us by Professor Forbes is one of peculiar difficulty to those who are not proficient in the higher branches of electrical science. We have here the conception of a magnetic current, and this is to some extent incompatible with our old and familiar notions under

which we supposed that only an electric current can flow, but that magnetism is a state of static equilibrium. When we speak of the flow of lines, say, in connection with the magnetic field of a dynamo, we do not mean that kind of flow which was described by the author, but merely the movement of a supposed free-unit pole or succession of such poles along certain lines in which a magneto-static stress exists. The flow described by the author takes place only during the formation of the field, and, if I understand him rightly, ceases when the field has become permanent. We have, in short, a magneto-dynamic phenomenon. I have always found it a help to the understanding of difficult electrical or magnetic problems if an attempt be made to represent the process involved by a mechanical model, and in this case I would suggest as a model, a centrifugal pump with vertical spindle, discharging water into a casing provided with a central and vertical rising main. Let the casing with its pump-wheel be submerged, and begin to revolve the latter. We know that the height to which the water will rise in the main is proportional to the square of the circumferential velocity of the wheel. But during the rise of the water in the main the ratio between velocity and height is disturbed by the inertia of the column of water which is being set in motion, and altogether a different kind of equilibrium exists. Now compare this with the action of a coil of wire, say a solenoid set vertically, with a long iron core projecting upwards. A current sent through the convolutions of wire corresponds to the rotary movement communicated to the pump-wheel. We know that this current cannot start suddenly, just as it is impossible to give the wheel its full speed of rotation all at once. We also know that the pole is not produced immediately at the outermost end of the rod, but as the field develops, the pole, by which I mean that region on the rod to which a suspended magnet would point, travels outward, reaching the top of the rod at the moment the current has grown to its full strength. Here we have, then, the phenomenon of a magnetic flow analogous to the rising surface of the water in the main of our hydraulic model. If we place a piston in the main, floating on the surface of the water, this piston will be raised and work will be performed against gravity; and similarly Mr. Kapp.

Mr. Kapp. a mass of free magnetism (placed round the rod in form of a ring, if such a thing were possible) would be raised during the period of the field's growth, and could be made to perform mechanical work. This work must be given by the current, which in consequence will be opposed by a correspondingly increased counter-electro-motive force, just as the pump will have to work against an increased pressure if the piston is resting on the column of rising water. When the field has assumed its permanent condition the work done by the current is solely due to the dead resistance of the wire, and in our hydraulic analogue, when the water has risen to such a height as to just balance the action of centrifugal force, the work which has to be done on the pump-wheel is solely due to friction. I shall be glad if Professor Forbes will tell us whether the analogy I have here sketched represents that which he understands by his term "magnetic current."

Professor Forbes. Professor FORBES: I must congratulate Mr. Kapp on giving a very pretty illustration of the idea of the way in which the magnetic effect is produced by a mechanical model; it is an analogous idea.

The Scrutineers handed in their report of the result of the ballot for Council and Officers, which the President declared to be as follows:—

President.

Sir CHARLES T. BRIGHT, M. Inst. C.E.

Vice-Presidents.

EDWARD GRAVES.
Colonel Sir FRANCIS BOLTON.
J. HOPKINSON, M.A., D.Sc., F.R.S.
WILLIAM CROOKES, F.R.S.

Ordinary Members of Council.

WILLIAM T. ANSELL, F.R.G.S.
Professor W. E. AYRTON, F.R.S.
Major CHARLES F. C. BERESFORD, R.E.
E. B. BRIGHT, M. Inst. C.E.
R. E. CROMPTON, M. Inst. C.E.
J. A. FLEMING, M.A., D.Sc.
Professor GEORGE FORBES, M.A., F.R.S.E.
Dr. J. H. GLADSTONE, F.R.S.
H. R. KEMPE, A.M. Inst. C.E.
Sir DAVID SALOMONS, Bart., M.A.
ALEXANDER SIEMENS.
AUGUSTUS STROH.

Associate Members of Council.

J. Brockie. | Colin Brodie.

C. H. B. Patey, C.B.

Honorary Treasurer.

Edward Graves.

Honorary Secretary.

Colonel Sir Francis Bolton.

Honorary Auditors.

J. Wagstaff Blundell. | Frederick C. Danvers.

Honorary Solicitors.

Messrs. Wilson, Bristows, & Carpmael.

The President: I am sure that the Scrutineers must have had a very laborious duty to perform, and I propose a hearty vote of thanks to them for their services. The motion was carried unanimously.

The meeting then adjourned.

THE LIBRARY.

ACCESSIONS TO THE LIBRARY FROM JULY TO DECEMBER 1, 1886.

By Alfred J. Frost, *Librarian.*

(*Works marked thus* (*) *have been purchased.*)

IT IS PARTICULARLY DESIRABLE THAT MEMBERS SHOULD PRESENT COPIES OF THEIR WORKS TO THE LIBRARY AS SOON AS POSSIBLE AFTER PUBLICATION.

Adams [Prof. W. G.] **and others.** Report to the Lords' Committee of Council on Education by the Committee of Advice with respect to the International Congress for the Determination of Electrical Units, to be held in Paris in April, 1884. 8vo. 18 pp. *London*, 1883

American Academy of Arts and Sciences. Proceedings. (New Series, Vol. XIII.; Whole Series, Vol. XXI.) Part II. From October, 1885, to May, 1886; pp. 247 to 573. *Boston*, 1886
[Exchange.]

* **Anon.** Mercator's Inland and Foreign Business and Social Telegraphic Pocket Code. Compiled by a Practical Telegraphist. 8vo. 159 pp. *London*, 1886

Astronomer-Royal [W. H. M. Christie]. Report to the Board of Visitors of the Royal Observatory, Greenwich, read at the Annual Visitation, June 5, 1886. 4to. 19 pp. *London*, 1886

Bateman-Champain [Col. Sir J. U.]. [*Vide* Mance.]

Burbury. [*Vide* Watson and Burbury.]

Carruthers [G. T.] The Cause of Electricity; with Remarks on Chemical Equivalents. 8vo. 26 pp. *Benares*, 1886

Cherrill [Nelson K.] Notions Élémentaires sur l'Éclairage Électrique par les Lampes à Incandescence. 8vo. 12 pp. *Lille*, 1886

Colonial and Indian Exhibition, London, 1886. Illustrated Handbook of Victoria, Australia. 4to. 108 pp. *Melbourne*, 1886
[Presented by the Royal Commission for Victoria.]

* **Dorn** [Felix]. Dorn's Code for Commercial Telegrams, for the use of Bankers, Merchants, and Manufacturers in their intercourse with Customers, Agents, Absent Partners, Travellers, &c. 8vo. 178 pp. *Bradford*, 1886

Electrical Units. [*Vide* Adams and others.]

Ellis [W.] Brief Historical Account of the Barometer. 8vo. 41 pp. [*Quart. Jour. of the Royal Meteorological Society*, Vol. XII., No. 59, July, 1886, pp. 31 to 71.] *London*, 1886

Ewing [Prof. J. A.] Effects of Stress and Magnetisation on the Thermo-electric Quality of Iron. [Abstract.] 8vo. 2 pp. [*Proc. Roy. Soc.*, No. 243, p. 246.] *London*, 1886

Franklin Institute. International Electrical Exhibition of the Franklin Institute, 1884. Report of the Examiners of Section XI. (Section I., Class 6)—Steam Engines. 8vo. 32 pp. Plates. *Philadelphia*, 1886

——— International Electrical Exhibition of the Franklin Institute, 1884. Report of Examiners of Section XXVI. (Section VII.)—Applications of Electricity to Artistic Effects and Art Productions; with which is incorporated Section XXV.—Applications of Electricity to Musical Apparatus. 8vo. 13 pp. *Philadelphia*, 1886

——— International Electrical Exhibition of the Franklin Institute, 1884. Report of Examiners, Section XXIII. (Section IVA., Class 8)—Electro-medical Apparatus. 8vo. 23 pp. *Philadelphia*, 1886

Gariel [C. M.] Traité Pratique d'Électricité, comprenant les Applications aux Sciences et à l'Industrie, et notamment à la Physiologie, à la Médicine, à la Télégraphie, a l'Éclairage Électrique, à la Galvanoplastie, à la Météorologie, &c., &c. Tome Second. 8vo. 552 pp. *Paris*, 1886

Hedges [Killingworth]. Precautions to be adopted on Introducing the Electric Light; with Notes on the Prevention of Fire Risks. 8vo. 188 pp. *London*, 1886

Hopkinson [J.], F.R.S., **and Hopkinson** [E.] Dynamo-electric Machinery. 4to. 28 pp. Plates. [*Phil. Trans.*, Part I., 1886, p. 331.] *London*, 1886
[Presented by Dr. J. Hopkinson.]

Houston [Edwin J.] Phenomena of Induction. 8vo. 5 pp. [*Journal of the Franklin Institute*, January, 1876.] *Philadelphia*, 1876

——— On the Synchronous-multiplex Telegraph. 8vo. 3 pp. [Read before American Phil. Soc., Dec. 7, 1883.] *Philadelphia*, 1883

——— Synchronous-multiplex Telegraphy in Actual Practice. 8vo. 6 pp. Plate. [*Journal of the Franklin Institute*, Sept., 1884.] *Philadelphia*, 1884

——— An Extraordinary Experiment in Synchronous-multiplex Telegraphy. 8vo. 6 pp. Plate. [*Journal of the Franklin Institute*, Sept., 1884.] *Philadelphia*, 1884

——— Photography by a Lightning Flash. 8vo. 3 pp. [Read before American Phil. Soc., Nov. 20, 1885.] *Philadelphia*, 1885

——— Glimpses of the International Electrical Exhibition of the Franklin Institute, 1884. The Telephone. 8vo. 179 pp. *Philadelphia*, 1886

Houston [Edwin J.] **and Thomson** [Elihu]. Electrical Phenomena. The Alleged Etheric Force: Test Experiments as to its Identity with Induced Electricity. 8vo. 5 pp. [*Journal of the Franklin Institute*, April, 1876.] *Philadelphia*, 1876

——— The Microphone Relay. 8vo. 4 pp. [*Journal of the Franklin Institute*, Vol. CVI. (1878).] *Philadelphia*, 1878

Institution of Civil Engineers. Minutes of Proceedings. Vol. LXXXV. 8vo. 528 pp. Plates. *London*, 1886

——— Minutes of Proceedings. Vol. LXXXVI. 8vo. 513 pp. Plates. *London*, 1886

——— Brief Subject Index, Vols. LIX. to LXXXVI., Sessions 1879-80 to 1885-86. 8vo. xxiii pp. *London*, 1886

Institute of Patent Agents. Transactions. Vol. IV. Session 1885-86. 8vo. 296 pp. *London*, 1886

[Exchange.]

Italian Telegraphs. Cenni sull' Amministrazione dei Telegrafi in Italia dalle Origini all' Anno 1885. Sm. 4to. 214 pp. *Roma*, 1886

Jamieson [Andrew]. Electric Lighting for Steamships. 8vo. 97 pp. Plates. [*Proc. Inst. Civ. Engrs.*, Vol. LXXIX., Session 1884-85, Part I.] *London*, 1885

[Presented by the Institution of Civil Engineers.]

* **Kittler** [Dr. Erasmus]. Handbuch der Elektrotechnik. Zwei Bände. [I. Band, 1 & 2 Hälfte.] 8vo. 667 pp. *Stuttgart*, 1885–86

Maier [Julius]. Arc and Glow Lamps. A Practical Handbook on Electric Lighting. 8vo. 375 pp. [The Specialists' Series.] *London*, 1886

Mance [Sir Henry C.] Official Report of the Persian Gulf Bushire-Jask Cable Expedition, 1885. Compiled under instructions from Col. Sir John U. Bateman-Champain, R.E. 8vo. 124 pp. *London*, 1886

[Presented by Col. Sir J. U. Bateman-Champain.]

Post Office Telegraphs. Connections of Telegraph Apparatus and Circuits. 59 plates, n.p. 8vo. *London*, 1886

[Presented by C. H. B. Patey, Esq.

Rogers [Henry Raymond]. A New Philosophy of the Sun. 8vo. 27 pp. [Read before the Chautauqua Society of History and Natural Science.] *Buffalo*, 1886

Royal Observatory, Greenwich Results of the Magnetical and Meteorological Observations made in the Year 1884. 4to. lii + lxxv pp. *London*, 1886

——— Rates of Chronometers on Trial for Purchase by the Board of Admiralty, at the Royal Observatory, Greenwich, 1886. 4to. 7 pp. *London*, 1886

[Presented by the Astronomer-Royal.]

School of Submarine Telegraphy and Electrical Engineering. Prospectus, &c. 4to. 24 pp. *London*, 1886

Thomson [Elihu]. [*Vide* Houston and Thomson.]

University College, London. Calendar. Session MDCCCLXXXVI.—LXXXVII. 8vo. 371 + lxxxi pp. *London*, 1886

Victoria, Australia. Illustrated Handbook of. 4to. 108 pp. [Colonial and Indian Exhibition, London, 1886.] *Melbourne*, 1886

[Presented by the Royal Commission for Victoria.]

* **Watson** [H. W.] **and Burbury** [S. H.] The Mathematical Theory of Electricity and Magnetism. Vol. I. Electro-Statics. 8vo. 268 pp. *Oxford*, 1886

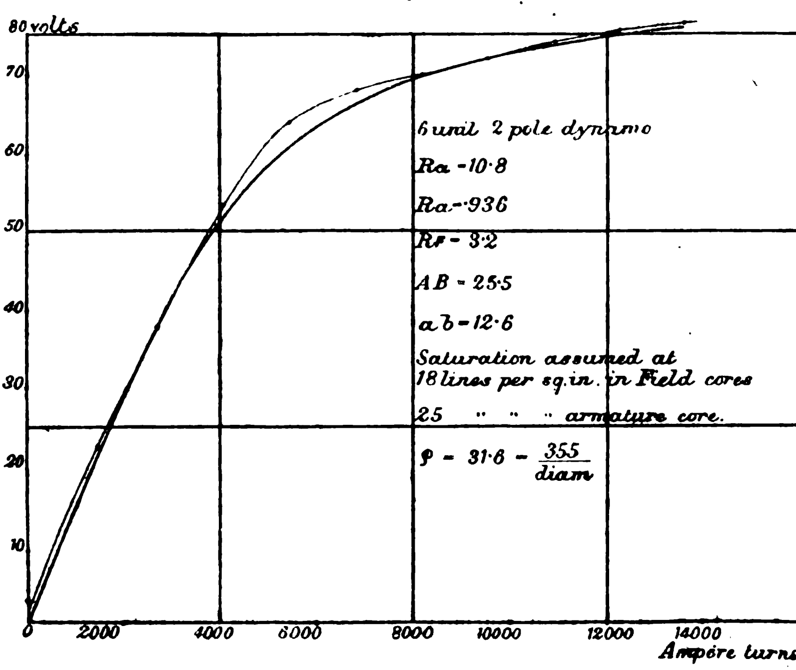
ORIGINAL COMMUNICATIONS.

A COMMUNICATION HAVING REFERENCE TO THE PRACTICAL APPLICATION OF KAPP'S METHOD OF CALCULATING THE CHARACTERISTIC.

A doubt as to the practical utility of Mr. Kapp's process for the Pre-determination of the Characteristic having been suggested by the remarks of some of the members during the discussion, the following independent tests may be of interest:—

The formula was first applied to the construction of a curve for a 6 unit 2-pole machine, the result of which is shown in Fig. 1,

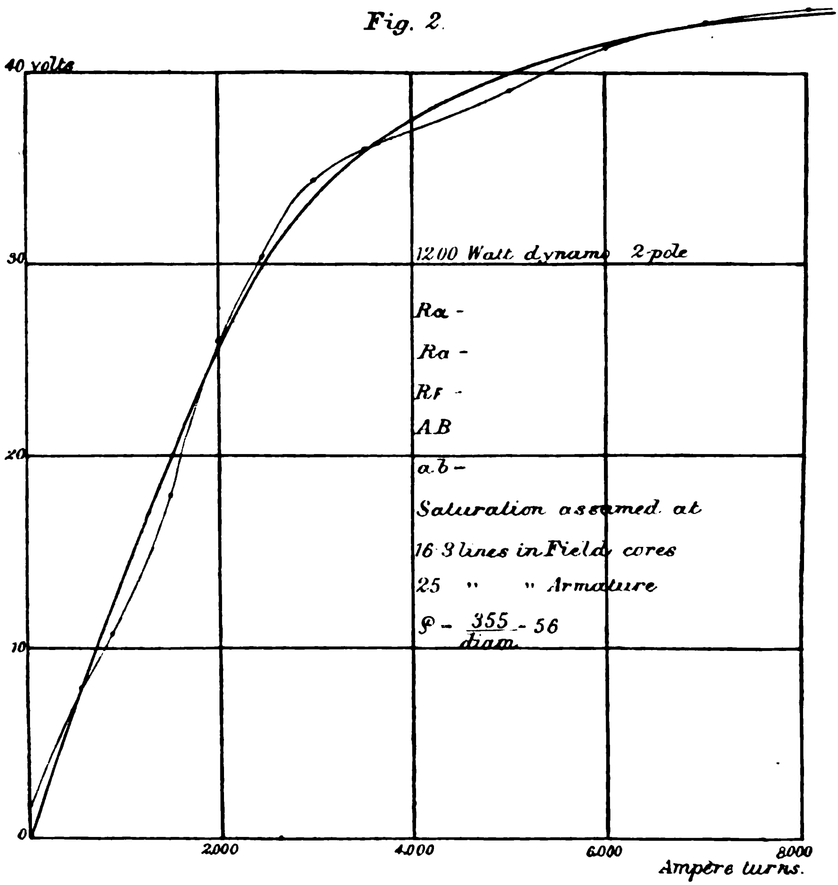
Fig. 1.



where the fine line is drawn through the experimental points and the calculated curve is traced by the thick line.

The value for ρ here obtained was then used to calculate the curve shown in Fig. 2 for a 1,200 watt dynamo of similar type.

Fig. 2.

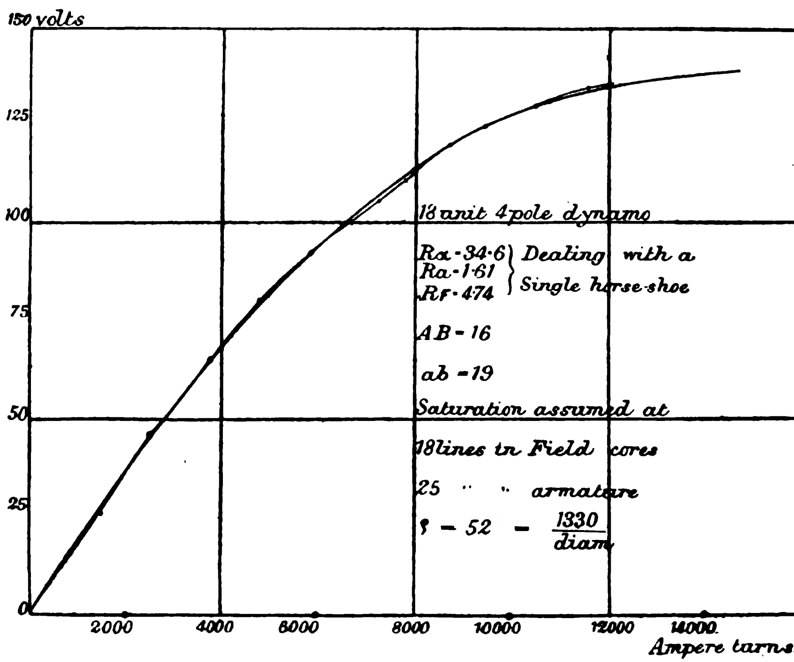


It will be noticed that a great discrepancy appears in the quality of the iron in the two cases. The only reason which the writer can advance is that the small forgings were supplied at short notice, whilst, with the larger ones, sufficient time was taken to anneal them thoroughly. A similar comparison was finally made for an 18 unit 4-pole machine (see Fig. 3), ρ of course being redetermined for this type.

In addition to the quantities given on the diagrams, the following are necessary in order to verify the results obtained:—

In Fig. 1	...	n	$= 1000$ and $Nt = 240$
" " 2	...	Ra	$= 22{\cdot}2$
		Ra	$= 1{\cdot}675$
		R_F	$= 5{\cdot}5$
		AB	$= 10$
		ab	$= 4$
		n	$= 2150$
		Nt	$= 180$
" " 3	...	n	$= 740$ and $Nt = 480$

Fig. 3.



It is noteworthy that if we imagine such a thing as complete saturation to be unattainable, then that portion of the magnetic circuit which is directly excited must, at some point, overstep the other portion in its degree of saturation whatsoever may be their relative sections. For, if we suppose the armature

indefinitely close to saturation point, no increase in the magnetic induction through it can take place except the pressure at the pole pieces becomes infinite, which means an infinite leakage through ρ in addition to the armature lines; thus, whatever may be the section of the field cores they must ultimately become more nearly saturated than the armature. The system adopted by Mr. Kapp provides for an infinite resistance in the armature core at saturation point, consequently by his formula the fields will always be found to saturate first.

The determination of ρ therefore presents no difficulty other than a correct assumption for the quality of the iron, for the horizontal tendency of the experimental curve may be very accurately judged and a maximum value for E_a obtained at which the field cores will be saturated.

We have then Z_1, p_1 and Z_2 as known quantities,

and $$z = Z_2 - Z_1 = \frac{p_1}{\rho},$$

whence $$\rho = \frac{p_1}{Z_2 - Z_1}.$$

It may also be remarked that the fall of potential in the armature and series winding in a compound machine on open external circuit being practically negligible, the proper exciting power due to the shunt winding may be taken directly from the calculated curve; thus, if makers can but obtain iron of reliable quality, the dynamo can be calculated in its entirety with all practical accuracy by this very valuable method.

GUY C. FRICKER.

9, Montserrat Road, Putney,
December 14*th*, 1886.

Eliot, Maine, U.S.A., *Sept.* 29*th*, 1886.

My dear Professor Hughes,

I have taken great interest in your researches into the phenomena of self-induction as manifested in different metals, and in the practical application of these discoveries; and I trust that you will pardon me for bringing to your notice one or two curious facts that have come under my own observation.

When I had built the Fire Alarm Telegraph in Boston, some time in the summer of 1852, I think it was, one of the signal-circuits was struck, and one or more of the electro-magnets in the signal-boxes had the wire with which they were wound (No. 23 B.W.G.) burned off. After testing the circuit carefully, and having mended all the breaks, we were still unable to charge the signal-magnets for some long time, perhaps three or more hours, the magnets seeming to have been paralysed so as to be unable to receive a charge of magnetism, but after a time, perhaps before the next day, they recovered their tone, so to speak, and worked well afterwards. I am not quite sure whether this occurrence was repeated or not; if it was, I could possibly find account in my notes at the time.

Another interesting occurrence was in the City of New York, in the year 1870, if I mistake not. The city was then having many miles of compound steel and copper telegraph wire strung from one signal-box to another; three of these wires ran over the Deaf Mute Asylum at Carmansville, but had not yet been connected to the signal-boxes for which they were designed. The lightning struck the building, cut off a cast-iron water pipe that was some three inches in diameter, and let all the water out of the tank that was in the attic of the four-story building. It also burned off one or more of these three wires, and from one, at least, it stripped all the copper for a distance of more than one hundred feet, leaving most of the copper in small bits, more or less than half an inch in length, lying on the ground, but leaving the steel wire unharmed, and as bright as a new tin pan. The compound wire had been made by drawing the steel wire through a bath of melted tin, then drawing a ribbon or skelp of copper over the tinned steel. Lastly, the copper was sweated to the steel by drawing the compound wire through melted tin. This stripped steel wire, with its coating of tin, remained bright for more than a day, but after that time it began to rust, and was soon replaced with new wire.

I remember that somewhere about that time an iron wire in the eastern part of Massachusetts was struck by lightning, and for many rods it was melted into short pieces, which dropped

upon the ground beneath the wire, and were found lying there by the line repair-man. I remember that in my early experiments in electric lighting, about the year 1859, I was trying a wire of aluminum for incandescent purposes. I was using a piece of wire that was perhaps five or six inches in length, and possibly three-hundredths of an inch in diameter, or a little more. The wire was suspended in form of a loop, and by means of a rheostat the current was increased until the light was very bright. I noticed that it was quite flexible, or rather flexile, for it had no elasticity, behaving in this respect in an entirely different manner from a wire of platinum. I heated and cooled it two or more times. I then noticed that it seemed shrivelled, somewhat like in appearance a shed snake-skin. I punctured the wire with a fine steel needle, and withdrawing the needle there followed a stream of melted aluminum to a length of rather more than the quarter of an inch; this metal cooled immediately, and remained sticking out from the wire after the current had been withdrawn. I suppose that the outer surface of the heated wire became oxidised, and perhaps hydrated, and in this condition had sufficient tenacity to hold together with its interior in a state of fusion, while its exterior was solid. While this loop was in this condition, solid without but fused within, I presented a small steel magnet towards it, and the loop was immediately attracted in virtue of the magnetic effect of the current; the presented pole caused the loop to twist so that its sides came together, short-circuiting itself, and thus burning off at the junction. I tried other wires, some of platinum, some of copper, and some of iron, but could not succeed in fusing them in the interior and have the surface remain solid. I did not try magnesium, not at that time having any on hand. I have often thought it would be interesting to try it.

I found the following empirical formula for the maximum current which a platinum wire would withstand was extremely useful to me in my early, and also later experiments, viz.:—

$$C = c_1 \frac{(w + t)}{\left(\frac{w}{t}\right)^{\frac{1}{4}}},$$

where w is the width of the strip or bar, t its thickness, and c_1 the strength of current which would fuse the wire when both w and t were unity—that is, which would fuse a bar that was half an inch square. I found this adapted to bars of iridium as well, and though it cannot be the exact expression, still it serves to guide one in making preliminary calculations. I tried many formulæ, but none answered so well as this. For this reason I have always advocated a lightning-rod of ribbon rather than round cross-section. I am glad to notice that your researches lead to the same form.

ELECTRO-DEPOSITION OF COPPER.

In the year 1868 I constructed a thermo-electric battery, which weighed not far from 1,500 lbs., and which contained 3,744 pairs, arranged 12 pairs in series by 312 pairs in multiple arc. The metals used in its construction were German silver for one of the elements, while the other element was an alloy of 96 parts of antimony and 56 parts of zinc. There was a little excess of zinc in the alloy, as was evidenced by little filaments of zinc which oozed out at the cool end of the element. When first constructed, the internal resistance of this battery was ·00025 ohm, also its electro-motive was ·3 volt, hence its external power was 90 watts. With this battery I deposited 12 lbs. of copper in 24 hours, consuming in that time 109 lbs. of coal. This was at about the rate of 9 lbs. of coal consumed for 1 lb. of copper deposited.

This is quite a contrast with the possibilities of the present day, when with a properly-arranged plant, using an engine that consumes but 1·75 lbs. of coal per hour per horse-power, and using a dynamo the efficiency of which is equal to 700 divided by 746, we can readily deposit more than 10 lbs. of copper by the combustion of only 1 lb. of coal.

The terminals of this battery were strips of sheet copper, the thickness being 1-16th of an inch, while the width was 4 inches. Yet if, after being in contact a few seconds on short-circuit, they were drawn suddenly asunder, the spark on separation was more than 7 inches in length.

About the dates 1866-67, I built many thermo-electric batteries, using the zinc-antimony alloys for one of the electrodes, and using German silver for the other element or electrode. Some of these batteries were in use for great lengths of time, one or more of them having been in use for as long a period as three years. This battery, which lasted longest, was in continuous use night and day depositing copper.

The general result was that the internal resistance increased with the lapse of time. A battery that was in continuous use night and day lasted longer than one that was cooled every day.

One great drawback to the profitable manufacture of these batteries was their extreme fragility—they would not bear transportation well. The thermo-electric battery, in my hands, did not give much promise of being a profitable source of electricity on a large scale. I never succeeded in realising more than one three-hundredth of the energy imprisoned in the coal, by even the best of those which I constructed.

About the year 1871 I constructed a dynamo with two circuits on the armature, and put a fly-wheel on to the armature axis. I put a galvanic battery on to one of the armature circuits, attaching the other circuit in series to the field. If I gave the armature a certain initial velocity of rotation, it would come to rest after a time; but if this initial velocity were just a little above a certain critical value, the armature kept in motion, gaining speed, until the work of friction balanced the work produced as an electro-magnetic engine.

I tried an interesting experiment with a much larger machine. It was this. I stretched about 20 inches of fine German silver wire between the armature terminals of this larger machine, and upon revolving the armature rapidly the wire became heated bright hot in the middle, but dark hot at and near the ends of the wire, and the light waved, growing brighter at each reversal of the direction of the current in the armature, thus showing that the propagation of the impulse was from the ends to the middle of the wire.

During the years 1872, 1873, and 1874, I constructed many dynamo machines for the United States Navy; these machines

all had the old form of Siemens armature. These armatures were about two inches in diameter by six inches in length. The iron used in their construction was cast-iron, both for fields and for armatures. When a machine was finished and ready to start up, I often placed a machine with its axis in a north and south direction. While the machine was in this position I might turn it rapidly or slowly, for a long or a short time, and still the magnetism would not "grow," as we used to say—that is, the magnetism would not come up, but change its position so that its axis would be east and west, and it would "grow" in ten or twenty seconds usually. Sometimes I imparted the needful amount of original, or rather initial magnetism, by touching one of the field-poles with a small permanent magnet.

After the field-magnetism was once permanently established, there was generally no trouble about the machine starting up promptly as soon as the crank was turned. This was the case with machines in which only cast-iron was used in their construction. I built one machine, using only the best Norway iron in its construction, and this machine behaved quite differently. In this case I could never get the field-magnetism to "grow" without the aid of a current from an outside source; and when it had fully come up, even with this aid, the magnetism of the field would immediately die away if the helping current were withdrawn. I have never discovered the reason for this, and yet the machine was built with exceptionally great care and attention.

I am greatly interested in Captain Sankey's paper on the economic deposition of copper by the electric current, and had I time this morning, and were it not wearying you too much, I would give you my solution of the same problem, which I worked out in 1884, about the time of the Electrical Exhibition in Philadelphia.

The results which I attained were substantially as follows:—Let A stand for the daily cost of superintendent, engineer, firemen, and interest and depreciation on the cost of the plant—in fact, all the permanent and unvariable sources of expense apart from the cost per diem of the vats and of the electricity; let B equal the internal resistance of the source of electricity; let R

represent the resistance of one vat and its connections; let N represent the number of vats arranged in series; let V equal the daily expense of one vat, this to include interest, depreciation, and care of attendance; let E equal the electro-motive force, in volts, of the source of the electricity; let C equal the strength of the current, in ampères, flowing through the N vats; let k equal the daily cost of one ampère-volt of electricity,—then, for a given fixed plant, that value of E which will refine the copper at the least expense per pound is obtained from the following equation,

$$E = \left(\frac{(A + N V)(B + N R)}{k}\right)^{\frac{1}{2}},$$

obtained by differentiating the original equation (1), supposing E alone to vary, and neglecting the value of e, the counter electro-motive force of the vats, which in most cases is small. The original equation is

$$(1)\ p_1 = \frac{A + k\,C\,E + N\,V}{N\,q\,C},$$

and the result of the differentiation shows that the expense per pound for refining, $k\,C\,E = A + N\,V$, is a minimum when the expense of producing the electricity is equal to the sum of all the other daily expenses.

Again, we might allow N alone to vary, all the other symbols remaining constant, and then we get the following equation for N, from which we deduce that, when the number of cells varies, we refine copper at the minimum cost, when the total expense of the vats multiplied by the total vat resistance is equal to the sum of these two other products, viz., A, the daily expense of the superintendence, etc., multiplied by the resistance of the source of the electricity, added to the cost of the electricity multiplied by the total resistance of the circuit, thus

$$N = \left(\frac{A\,B + k\,E^2}{R\,V}\right)^{\frac{1}{2}},$$

therefore $N\,V\,N\,R = A\,B + k\,C\,E\,(B + N\,R)$.

I found, too, that the number of pounds per horse-power that could be refined daily could be determined by the following equation,

$$\frac{N\,q\,C}{p\,C\,E} = \frac{q}{p\,r\,z\,D} \times \frac{N\,R}{B + N\,R},$$

in which p is the number of horse-powers equivalent to one volt-ampère; r is the resistance to conduction between two electrodes each one foot square and one foot apart; z is the distance apart of the electrodes, expressed in feet; D is the density of current used in ampères per square foot; and q equals daily deposits by one ampère. With proper density of solution, and proper temperature and acidity, I have obtained good results throughout all ranges from D = 1 to D = 50, and even higher.

But I fear to weary you with these crudely put together items, and must plead ill-health as part of my excuse. I will close by wishing the best success to the "Society of Telegraph-Engineers and Electricians."

Very truly yours,

MOSES G. FARMER.

95, MILK STREET,
BOSTON, MASS., *October 4th*, 1886.

F. H. WEBB, ESQ.

My Dear Sir—

I have been much interested in reading in the *Journal* the paper on "Long-Distance Telephony," read by Mr. Preece at the regular meeting May 13th, 1886. I also have read with interest the discussion thereupon. The references made by Mr. Preece himself to Telephony in the United States were characterised by his accustomed clearness and accuracy. I cannot however, say the same with respect to the remarks of one or two of the speakers.

On page 293 of the *Journal*, No. 62, Mr. Van Rysselberghe is reported as having said: "In reply to the question, whether "inter-urban or international Exchange working will pay, I think "we cannot base our calculations upon America, for the experience "there is no guide.

"It is well known that at present in America there is a "difficulty, not of a technical nature, but of the nature of an

"agreement between the Western Union Telegraph Company and "the Bell Telephone Company, under which the Bell Company "cannot, without the consent of the Western Union Company, "put up telephone circuits for distances over ten miles. The "Boston and New York line is ready, and could at once be "put into operation, but the Western Union Company will "not allow it.

"The agreement was for 19 years; and as long as that stands "there will be no long-distance telephony in America."

Upon page 297, Professor Silvanus P. Thompson, acquiescing in the above remarks, goes on to say: "I would first of all say "that the Western Union Telegraph Company were very wise in "their generation when they made that arrangement with the "American Bell Telephone Co. that Mr. Van Rysselberghe "mentioned."

Then, on page 300, I find that Mr. Geo. A. Mason observes— "Secondly, the interest of the Western Union Telegraph Co. and "the American Bell Telephone Co. is a joint interest, because the "Western Union owns 45 per cent. of the Bell Telephone interest, "therefore the interests must be identical."

These statements are all erroneous. It is not, however, surprising that the notion of Mr. Van Rysselberghe obtains, to some extent, in foreign countries, since even in the United States it is frequently intimated that the development of the long-distance telephone has been purposely retarded for the protection of the interests of the Western Union Telegraph Company, as required by its agreement with the American Bell Telephone Co.

It is true that there is a business contract between these Companies, in which the Western Union Telegraph Company is the party of the first part; the Bell Company being the party of the second part.

That section of the contract, which refers to the above matter, reads as follows:—

"Article 3. (1) The right to connect telephonic district or exchange systems for the purpose of personal conversation between persons at the instruments, and the right to use telephones on all lines not forming a part of a telephonic district or exchange

system for such personal conversation (except so far as licenses are to be granted to the party of the first part under Article 14) *are to remain exclusively with the party of the second part, and those licensed by it for the purpose.* But such connecting and other lines are not to be used for the transmission of regular business messages, market quotations, or news for sale or publication, in competition with the business of the Western Union Telegraph Co. or that of the Gold and Stock Telegraph Co. And the party of the second part, so far as it lawfully and properly can prevent it, will not permit the transmission of such general business messages, market quotations, or news for sale or publication, over lines owned by it, or by corporations in which it owns a controlling interest, nor license the use of its telephones or patents for the transmission of such general business messages, market quotations, or news for sale or publication, in competition with such telegraph business of the Western Union Telegraph Company, or that of the Gold and Stock Telegraph Company.

"(2) The terms 'general business messages' and 'telegraph messages,' or 'messages for hire,' are defined to mean *all communications on behalf of other parties than those who directly communicate by the telephone by themselves or their servants or agents personally present at the instruments;* and no person engaged in the business of transmitting messages for other parties shall be authorized or knowingly allowed by the party of the second part, or its servants or agents, to transmit such messages through the telephone."

Thus it is evident that the only restriction upon long-line telephony, by virtue of this much-cited contract, has nothing to do with the length of the line, but simply provides that the sender and receiver of the messages must themselves operate the telephones.

The statement of Mr. Mason is erroneous. The Western Union Telegraph Company has no proprietary interest in the Bell Telephone Co.

I forward herewith a copy of the last *Exchange List* published by the American Bell Telephone Co. Pages 10 to 14 are

completely filled with the list of inter-urban lines of varying length, which Mr. Van Rysselberghe may figure out for himself. Since the statements I take exception to were publicly made and published in the *Journal*, I trust that my correction will be afforded similar courtesy.

Yours very truly,

THOS. D. LOCKWOOD.

ABSTRACTS.

Professor W. OSTWALD—ELECTRO-CHEMICAL RESEARCHES.

(*Phil. Mag., Vol.* 22, *No.* 135, *Aug.*, 1886, *pp.* 104-118).

All reactions of acids, dependent on the characters rather than on the nature of the constituents of the acids, occur with an intensity which is different in each case, but is always proportional to an affinity constant which is itself dependent only on the character of the acid, and not at all on the nature of the reaction.

There must be a distinct connection between the reactions of acids and the electrical conductivity of these acids. For according to Faraday's law, the ions always transmit the same quantity of electricity independently of their chemical nature; and according to the theories of Williamson and Clausius, there is a continual exchange of atoms among the reacting molecules, while the free ions continually displace equivalent elements or radicles from the molecules, so that the more rapidly the ions exchange the more rapidly will electricity be conducted.

The experiments of the author on the catalytic decomposition of methylic acetate and the inversion of cane-sugar have led to results which show that the electrical conductivities of the various acids are proportioned to the velocities of the change of methylic acetate into methylic alcohol and acetic acid, and the inversion of cane-sugar brought about by these acids. The degree of dilution of the acid exerts a great and varying influence on the conductivities.

The molecular conductivities (by which is meant the conductivity of the acid containing in solution between two parallel electrodes, one centimètre apart, one equivalent in grammes of the acid) of the stronger acids, such as hydrochloric, nitric, ètc., are nearly the same: they slowly increase and reach a maximum, when the dilution increases, equal to about 90 at a dilution of 512 litres. With the monobasic organic acids the molecular conductivity increases in every case, but in a very varying degree. The increase is greater the smaller the conductivity of the acid; it is also greater for weak than for strong acids, and greater for small than for large dilutions. Excepting formic and butyric acids, the dilutions at which the molecular conductivities of the monobasic acids exhibit equal values always bear a constant relation to each other. The experiments on about 100 monobasic acids seem to show the existence of some natural law, which may perhaps be expressed by a fairly simple analytical expression. A simple equation has been found of the form

$$\tan. m = \left(\frac{v}{v_0}\right)^{\cdot 4134}$$

but it is open to objections, and it is desirable to find a simpler one which does not comprehend an angle-function. The behaviour of polybasic acids is different from that of monabasic acids, depending perhaps on the participation of the second and third atom of hydrogen in the electrolysis. The weaker dibasic acids, whose normal salts are neutral, show an increase of conductivity over the monobasic acids when the solutions become dilute: this advance of conductivity is exhibited sooner and to a greater extent the stronger the acid. The point at which the second hydrogen atom of a very strong dibasic acid (as sulphuric acid) begins to take part in the electrolysis is situated in the concentrated solution. Dilute solutions behave similarly to those of monobasic acids, if we compare equivalent with equivalent, and not molecule with molecule.

LORD RAYLEIGH—THE ENERGY OF MAGNETISED IRON.

(*Phil. Mag.*, *Vol.* 22, *No.* 135, *Aug.*, 1886, *pp.* 175-183.)

The results of observations are usually expressed by curves showing the relation between the magnetic induction and the magnetising force. This relation is not of a determinate character. In a cycle of operations during which the magnetising force is first increased and is afterwards brought back to its original value, the induction is always greater on the descending than on the ascending course. In considering the cycle of operations gone through in carrying very soft iron from strong negative to strong positive magnetisation and back again, we see that in the first part the inductive E.M.F. is in aid of the magnetising current, and work is received from the iron; afterwards, on the ascending side, work is put into the iron. On the descending side work is first of all received from the iron during a short part of the cycle, and subsequently work is expended. The case, therefore, is not one of storing energy recoverable with small relative loss, but rather one of almost continuous dissipation.

The opposite opinion, which is most generally held, viz., that energy is stored in the iron, would seem to depend on a confusion between closed and unclosed magnetic circuits. The available energy in a short bar of magnetised iron, for instance, depends on the free polarity at the ends. So, too, where energy is apparently obtained from the magnetisation of a closed circuit,—as, for instance, in pulling away the armature of an electro-magnet,—the energy is really obtained from the mechanical work done.

The author further considers the curves deduced by Professor Ewing from his experiments with respect to the magnetisation of ellipsoids of various forms.

Sir JAMES N. DOUGLASS—FLUTED CRATERLESS CARBONS.

(*Proc. Roy. Soc.*, *Nature*, *Vol.* 34, *No.* 870, 1*st July*, 1886, *p.* 209.)

The carbons first used at the South Foreland Lighthouse in 1858 were awn from retort carbon, and were rectangular in section, having a sectional

area of 39 square millimètres. The mean horizontal intensity of the arc was 670 candles, or 17 candles per square millimètre of section. At the late experimental researches at the same place, round carbons 35 and 50 millimètres in diameter were used with currents of 206 and 372 ampères respectively, giving only 12 candles per square millimètre of section.

The relative inferiority of the large carbons seems to be due to the loss of a large portion of the most intense part of the arc which is confined within the crater, and to the arc shifting its position from one point to another of the carbons. Moreover, the use of these large-sized carbons is impossible where flashing signals have to be given, as the duration of the flash would vary with the diameter of the carbon used, viz., 35 mm. in clear weather, and 50 mm. in thick weather. This variation would of course obscure the individuality of each lighthouse as shown by its flashes.

By employing fluted carbons the difficulties referred to may be overcome; for the cross-section being star-shaped, the sectional areas may be altered by varying the solid centre, while the diameter is kept the same. Further advantages are a larger vertical angle of radiant light from the arc, with a higher coefficient of intensity in consequence of the unobstructed radiance through the fluting at the points of each carbon, and a steadier light as the arc is localised at the centre of the star-shaped cross-section.

T. D. LOCKWOOD—RECENT ADVANCES IN TELEPHONY.

(*The Electrician and Electrical Engineer, New York, Vol.* 4, *No.* 54, *June*, 1886, *pp.* 218-222.)

There have been great advances made in the development of long-distance telephony in late years: these have chiefly been in two directions—in the circuit, and in the transmitter. What has really rendered long-distance telephony possible is the use of copper wire for the conductors. So long as iron wires were employed, it was impracticable to speak over any distance. By many persons the improvement which is due to the use of copper wire was at first attributed to the decreased resistance of the line. But this decreased resistance would not account entirely for the greater facility of communication; for if we take two lines, one built of copper and the other of iron, but of equal resistance, the copper line always gives the better results. The explanation of this is to be found in the researches of Professor Hughes on induction. He has shown that the E.M.F. of the extra current in a solid iron wire is much greater than in a similar copper wire; and that iron has three times the resistance for a current in the variable phase that it has for a permanent current, which is not the case with copper.

The transmitter has undergone various improvements, so that the amount of current transmitted might be intensified, in order to override the disturbing currents due to extraneous causes. The receiver did not call for improvement, as it was already as sensitive as was desirable.

H. LECHATELIER — CHANGE IN THE E.M.F. OF THERMO-ELECTRIC COUPLES, PRODUCED BY A RISE OF TEMPERATURE.

(*Comptes Rendus, Vol.* 102, *No.* 14, *April* 5, 1886, *pp.* 819-822.)

Thermo-electric couples have, according to Avenarius and Tait, an E.M.F. increasing between 0° and 400° according to a parabolic function of the absolute temperatures as given by the formula

$$E = A(T_1 - T_0) + B(T_1^2 - T_0^2),$$

which may be simplified by making T_0 equal zero, or, in other words, by keeping one of the junctions at the temperature of melting ice; the formula then becomes

$$E = AT + BT^2$$

It has always been supposed that this law held good for temperatures above 400°, but no experimental proof has ever been given. By keeping one junction at 0° in melting ice, and by covering the other junction, suitably protected by a layer of magnesia, with a thin sheet of various metals, the melting points of which are known, the author has been able to push his observations considerably above 400°. The E.M.F. was measured by means of a Deprez-d'Arsonval galvanometer, and the moment at which the metal fused was indicated by a momentary stoppage of the movement of the galvanometer. The couples were composed of wires 0·5 mm. in diameter and 1 m. long.

It results from the experiment that the law of Avenarius and Tait holds good also above 400°, to the same degree of approximation as below that temperature, up to a limiting value which is different for different couples. Above this limiting value the coefficients A and B in the above formula have different values.

From the E.M.F. of a couple it is of course possible to calculate the temperature of fusion, and in a table the author gives the value thus calculated, as compared with the generally accepted values. The greatest difference does not exceed 20°, which is an approximation quite sufficient for temperatures above 500°.

LEDEBOER—COEFFICIENT OF SELF-INDUCTION OF A GRAMME DYNAMO.

(*Comptes Rendus, Vol.* 102, *No.* 26, *June* 28, 1886, *pp.* 1549-1551.)

From the experiments made on a dynamo of the ordinary type, it appears that there is perfect accord between the magnetic field and the extra current: the two curves, in fact, coincide throughout. On comparing this curve with the characteristic curve, there was found to be no proportionality between their ordinates, and that for large currents the E.M.F. falls much more quickly than the strength of the field. In another series of experiments on the coefficient of self-induction of the armature it was found that this coefficient is decreased by one-half when the electro-magnets are powerfully

excited. In this case the extra current is represented by a straight line, which shows that the coefficient of self-induction is independent of the current in the armature, contrary to what usually occurs in the case of bobbins with an iron core.

Theory points out that if the magnetisation of the core is not affected by the current in the bobbin, the effect must be the same as if the core were absent. An experiment was made on this point. Two concentric bobbins with an iron core were used, and, the core being removed, the coefficient of self-induction of the outside bobbin with a very weak current was found to be 0·107; on replacing the iron core, the value was 0·403. The last measurement was then repeated with a very strong current in the inner coil, and the coefficient was then 0·110. Hence the effect of the strong continuous current was to annul the influence of the iron core.

CORNU and POTIER—VERIFICATION OF VERDET'S LAW.

(*Journal de Physique, Vol.* 5, *May*, 1886, *pp.* 197-203.)

The experiments were made with two electro-magnets of special form placed face to face, and provided with holes through which could be passed the tubes containing the liquid to be experimented upon. The maximum current used rarely exceeded 4 ampères, the resistance of the wire on the bobbins being 17·3 ohms, with about 900 convolutions.

Since the rotations which were to be observed in the direction almost perpendicular to the lines of force were very slight, it was very desirable to use a liquid of high rotary power. The liquid finally chosen was a solution of bi-iodide of mercury in iodide of potassium, which, when saturated, has a rotary power ten times that of water, and is sufficiently transparent with the yellow sodium light used.

The values obtained, when reduced so as to eliminate the effect of the glass, came out somewhat smaller than those calculated from Verdet's law.

In a second series of experiments with a shorter tube, the excess of the calculated values over the observed ones was less. The difference proves that the field was not sufficiently uniform in the direction of the lines of forces passing through the centre of the apparatus, the lines, in fact, tending to scatter. This was verified by the rotation produced by a flint glass lens in different positions in the magnetic field. As Verdet's law requires that the lines of force should be parallel, a still shorter tube was tried, with the result that the observed values agreed much more nearly (within two per cent.) with those calculated.

MASCART—MAGNETISATION.

(*Journal de Physique, Vol.* 5, *July*, 1886, *pp.* 298-301.)

When a feebly magnetic body is placed in a uniform field, it takes on a magnetisation parallel and proportional to the magnetising force. The coefficient of magnetisation, k, is the ratio of the magnetic moment of the body

per unit of volume to the intensity of the field. With strongly magnetic bodies the phenomenon is complicated by the reaction produced by the induced magnetism.

For isotropic bodies of a form such that a uniform magnetisation produces a constant reaction, as in the case of a sphere, an ellipsoid, or a cylinder of infinite length, the intensity of magnetisation A is given by the formula

$$A = \frac{k}{1 - k\,C} F,$$

where C is a constant depending on the geometric form, and F the intensity of the field. Experiments show that the coefficient k is a function of the magnetising force. Neither spheres nor ellipsoids are suitable forms for determining experimentally the value of k, and it is therefore necessary to fall back on the cylindrical form. A cylinder of infinite length not being possible, an equivalent effect may be obtained by using a closed ring magnetised in the direction of its length. The ring has a coil on it at one point in connection with a galvanometer; the throw of the galvanometer on opening and closing the magnetising circuit, and the measurment of the current, lead to the solution of the equation giving the value of k.

Experiments made by the author with very long rods, in comparison with their diameter, led to results quite concordant with those obtained for closed rings. Hence, if the cylinders are 500 times longer than their diameter, they may safely be used instead of closed rings.

LIPPMANN—ABSOLUTE SPHERICAL ELECTROMETER.

(*Journal de Physique, Vol.* 5, July, 1886, *pp.* 323-325.)

This instrument consists essentially of an insulated metallic sphere, which can be brought to the potential to be measured. The sphere is divided symmetrically into two halves which repel each other when electrified with a force f, and it may be shown that $f = \frac{1}{8} V^2$.

There are several ways of measuring f, of which the author has adopted the following:—One of the hemispheres is fixed, the other is suspended in the proper position by three threads. When the movable hemisphere is repelled, the position of the threads makes an angle a with the ordinary position. This angle may be measured by the aid of a mirror attached to two of the threads, and then if p is the weight of the hemisphere, since $f = p \cdot \tan. a$,

$$p \cdot \tan. a = \frac{1}{8} V^2.$$

It is only necessary, therefore, to know the value of p exactly, and it is immaterial what is the size of the sphere. For protection from outside disturbances, the two hemispheres may be placed inside a spherical concentric envelope which is in communication with earth. If a and b are the radii of the two spheres,

$$p \cdot \tan. a = \frac{1}{8} \cdot \frac{b^2}{(b - a)^2} V^2.$$

SCHWEDOFF—A THERMO-MAGNETIC PHENOMENON.

(*Journal de Physique*, *Vol.* 5, August, 1886, *pp.* 362-365.)

If iron be heated to incandescence it is no longer attracted by a magnet. A horizontal ring of iron is suspended so as to be movable round a vertical axis. It will be unaffected by the presence of a magnet, as the resultant of all the forces will pass through the axis. But if one half is at a bright red heat while the other half is cold, the magnet acting only on the cold half will cause a continual rotation of the ring. However small may be the resistance of the pivot and of the air, still there will always be some work expended in overcoming it. It would seem, therefore, that some of the heat given to the ring must be converted into work.

If a N. pole of a magnet is brought near a suspended iron ball, three forces are at work on the molecules of the iron—the directive force of the N. pole, the mutual action of the molecular magnets in their new position, and the magnetic elasticity or force depending on the matter of which the ball is made. This latter is influenced by the heat and becomes greater, overpowering the directive force of the magnet.

It is also clear that heat can by created in the ball by reversing the cycle of operations—that is to say, by taking it away from the north pole when it is cold, and bringing it near when it is red hot.

A. PALAZ—RESEARCHES ON THE SPECIFIC INDUCTIVE CAPACITY OF SOME DIELECTRICS.

(*Journal de Physique*, *Vol.* 5, *August*, 1886, *pp.* 370-377.)

The capacities of two condensers may be compared by a method analogous to the comparison of resistances by the Wheatstone bridge, the condensers being placed in two arms of the bridge. The battery may be replaced by an induction apparatus, and the galvanometer by a telephone; there will then be no sound in the telephone when $R\,C = R^1\,C^1$.

With this arrangement, the mathematical theory of which is fully treated, experiments have been made with various liquid dielectrics, such as petroleum, toluol, benzol, etc. The two condensers were cylindrical and of equal dimensions, the layer of liquid being 1 mm. thick. One served as a standard with which the second one was compared, first with air as the dielectric, and then with the liquid. By sliding contacts on German silver wires it was possible to determine very exactly the resistances in the two arms of the bridge, and hence the maximum error in the value of the specific inductive capacity was 0·002.

By varying the strength of the current in the primary of the induction coil, the potential to which the condensers were charged could be varied between 1 and 64, but no variation whatever was noticed in the specific inductive capacities of petroleum, toluol, or benzol.

A very considerable variation was noticed, however, for changes in temperature, but the series of experiments were not extended over a sufficiently

wide range of temperatures to enable the exact law to be arrived at, though the change in the specific inductive capacity is probably represented by the formula

$$D = D_o + \alpha t + \beta t^2.$$

The equality of the square root of the coefficient of specific inductive capacity and of the index of refraction for waves of infinite length, was also investigated, but even on taking into account the variations due to temperature the numbers do not agree very closely.

The author also investigated if a powerful magnetic field would have any effect on the values of the specific inductive capacities, but no trace of any action was apparent.

ERIC GÉRARD—SELF-INDUCTION.

(*La Lumière Electrique, Vol.* 20, 1886, *pp.* 292-298.)

Variable currents play a great part nowadays in quick working telegraph instruments, in telephones, in alternate-current machines, etc.; and in all cases where we have variable currents, we have also induced currents either in the same wire or in neighbouring wires. Where induction takes place between two wires, it may be expressed by the equation

$$M = 2\,l\left(l \,.\, \frac{2\,l}{h} - 1\right),$$

l being the length for which the wires are parallel, and h their distance apart. In the case of self-induction, if E is the E.M.F. in the circuit, R the resistance, L the coefficient of self-induction, ϵ the base of the natural logarithms, i the strength of the current, t the time since the closing of the circuit, then

$$i = \frac{E}{R}\left(1 - \epsilon^{-\frac{R}{L}t}\right),$$

and as $\frac{R}{L}$ is generally a large number, if t becomes of some value, the equation becomes practically that of Ohm.

If now the E.M.F., instead of being constant, as supposed in the preceding case, varies according to a given law, then we obtain a more complicated expression. In the case where the circuit has a coefficient of self-induction L, a resistance R, and the E.M.F. has a periodic time T, we obtain for each moment a current

$$i = \frac{E_o}{\sqrt{R^2 + \frac{4\,\pi^2\,L^2}{T^2}}}\ sin\left(\frac{2\,\pi\,t}{T^2} - \phi\right),$$

ϕ being given from $t\,g\ 2\,\pi\,\phi = \frac{2\,\pi\,L}{T}$.

The phenomenon of self-induction has the effect of producing a retardation in the undulations of the current, and of diminishing its strength, as if the resistance had increased in the ratio of R to $\sqrt{R^2 + \frac{4\,\pi^2\,L^2}{T^2}}$; this quantity under the root representing the apparent resistance of the circuit.

Self-induction in the bobbins of the telephonic translators considerably weakens the current, but the self-induction is itself diminished by the mutual induction of the neighbouring bobbins; or, as it is sometimes stated, the mutual induction diminishes the apparent resistance.

Not only may self-induction occur in the case where the current follows a spiral path, as in a bobbin, but it may also arise in straight wires. For the rectilineal current in a straight conductor may be looked upon as made up of several parallel elementary currents which react on each other so as to give rise to an E.M.F. of induction opposed to that which produces the current.

The formula for the induction of parallel currents has been already given, and in the case of a single wire of radius r, in which the mean distance of the several elementary currents is $h = 0{\cdot}07788\ r$, the coefficient of self-induction becomes

$$L = 2\,l\left(l \cdot \frac{2\,l}{r} - 0{\cdot}75\right).$$

This is in the case of non-magnetic wires; but for wires of magnetic metals the induction is more powerful, for each time that a current is started in the wire the external layers are magnetised. The coefficient of self-induction has therefore to be increased by a quantity depending upon the magnetisation, and becomes

$$L = 2\,l\left(l \cdot \frac{2\,l}{r} - 0{\cdot}75 + K\right).$$

The author has carried out some experiments on the general plan of Professor Hughes, but with some differences in the arrangement of the apparatus; his results confirm the calculations given above.

Conductors of square section have less self-induction than those of circular section, because the elementary currents have a greater mean distance in the former case. The use of ribbon conductors for lightning-rods does not therefore depend on their greater surface-conductivity, as used to be supposed, but on their lower self-induction.

In the case of compound wire, *i.e.*, a steel core electro-plated with copper, part of the current passes through the steel core, and part through the copper covering: these two parallel currents magnetise the exterior layers of the core in opposite ways, and consequently the self-induction is less. If the copper were inside and the steel outside, the opposite effect would be produced.

J. WETZLER—NEW SYSTEM OF DUPLEX TELEGRAPHY.

(*La Lumière Electrique, Vol.* 20, 1886, *pp.* 219-221.)

Edison has lately brought out a new system of duplex working between any two stations. This is the Phonoplex, or Way-Duplex. Each station is provided, in addition to the ordinary relay and sounder, with a phone. This instrument is, in fact, a telephone with a permanent horse-shoe magnet and a steel ring resting on the diaphragm. This ring, being able to move in a vertical plane only, gives very distinct raps when a current passes in the telephone

To work the phone there is a local battery with a key, the circuit being completed through a relay: this relay puts in circuit with another battery the primary of an induction coil. When the key is depressed, the lever of the relay opens the circuit of the battery, and an extra current is set up in the induction coil, whence it passes to the line: the extra current is reinforced by a condenser being joined up to the circuit. The intense extra current has no effect on the sounder relay, which, however, responds to the ordinary current, but it acts on the phone, causing the steel ring to give very distinct signals.

G. COLOMBO—CENTRAL STATION AT MILAN.

(*La Lumière Electrique, Vol.* 20, 1886, *pp.* 481-483.)

The lighting is effected by means of the transformers of Zipernowski, Deri, and Blathy. The generating machine is of the type S W_6 of Ganz & Co., with 20 magnets, and giving therefore, at a speed of 250 revolutions, 5,000 alternations per minute. The current for which the machine was built is 55 ampères at an E.M.F. of 1,300 volts, but for the present only 22 ampères are required. The exciting current is 30 ampères and 100 volts, and is furnished by part of the current of the machine being converted into a continuous current by means of a commutator. Both the main current and the exciting current pass through a "compensator," by the action of which the E.M.F. at the terminals of the transformers is kept constant. The main current is conveyed from the central station to the Theatre Dal Verme by means of a concentric cable, the distance being 1,260 yards. In the theatre there are at present three transformers of 10 horse-power each, by which the E.M.F. is reduced to 96 volts.

P. H. LEDEBOER—DETERMINATION OF THE COEFFICIENT OF SELF-INDUCTION.

(*La Lumière Electrique, Vol.* 20, 1886, *pp.* 529-538.)

The method employed is that of the Wheatstone bridge, the coil or electro-magnet being in one branch. The resistance of the coil is first balanced in the ordinary way. The opening and closing of the battery circuit then give rise to induced currents depending on the electro-magnetic capacity of the coil; and from the deflection of the galvanometer the coefficient of self-induction can be determined.

From the application of Kirchoff's laws to the currents and resistances in the bridge, four equations are obtained, which, when simplified, reduce to the general formula

$$\int i_0 \, dt = \frac{L \, l' \, I}{l\,(R' + l') + g\,(l + l')}$$

where L is the coefficient of self-induction of the coil, I the current in it, l, l', R′ the resistances of the three arms of the bridge, g that of the galvanometer, and i_0 the current in the galvanometer circuit.

To determine L from the above equation, we must know not only the resistances above mentioned, but also the quantity of electricity, $\int i_0\, dt$, which passes through the galvanometer. This may be arrived at by comparing the throw of the galvanometer needle due to the induced current with the deflection occasioned by the permanent current which passes when the balance of the bridge is upset by the addition of a small resistance, r, to one arm, for we have finally, supposing I has not been altered by introducing r,

$$\int \frac{i_0 \cdot dt}{i'_0} = \frac{L}{r}.$$

To compare the throw, δ, produced by the quantity of electricity under the integral with the deflection, α, produced by the current, i'_0, we have

$$\int \frac{i_0\ \ dt}{i'_0} = \frac{\delta}{\alpha} \times \frac{T}{\sqrt{\pi^2 + \lambda^2}} \times \epsilon^{\frac{\lambda}{\pi} \tan.^{-1} \frac{\pi}{\lambda}},$$

where λ is the logarithmic decrement, the right-hand side of which equation for a ballistic undamped galvanometer becomes simply

$$= \frac{\delta}{\alpha} \times \frac{T}{\pi},$$

so that we obtain

$$L = r\frac{T}{\pi} \cdot \frac{\delta}{\alpha},$$

where T is the time of one oscillation, which can be readily determined.

P. H. LEDEBOER.—MEASUREMENT OF THE COEFFICIENT OF SELF-INDUCTION BY MEANS OF A GALVANOMETER OF DEPREZ-D'ARSONVAL.

(*La Lumière Electrique, Vol.* 21, 1886, *pp.* 6-18.)

To make a measurement of the coefficient of self-induction by means of this galvanometer (see *Journal*, Vol. 14, p. 448), we begin by determining the constants of the galvanometer, viz., the time of one oscillation without a current, the deflection corresponding to one micro-ampère, and the resistance for which the galvanometer is just dead beat.

These constants having been determined once for all, a Wheatstone bridge arrangement is set up, the experimental coil being in one arm, and the resistance of the galvanometer circuit being so arranged as to be always the same, and equal to that for which the square roots of the equation of motion of the coil of the galvanometer are equal.

The actual measurement then consists of nothing more than the observation of the deflection produced on making or breaking the battery circuit, the strength of the current being determined both before and after this observation. When the deflection is too great the galvanometer can be shunted. The formulæ used are—

I. *Without shunt:*

$$L = \frac{T}{\pi} \cdot e \cdot \frac{i}{\alpha} \cdot \frac{\delta}{I} \left\{ g\left(1 + \frac{R}{R^1}\right) + R + l \right\}.$$

II. *With shunt:*

$$L = \frac{T}{\pi} \cdot e \cdot \frac{i}{a} \cdot \frac{\delta}{I} \left\{ g \left(1 + \frac{R}{R^1} + \frac{R + l}{S} \right) + R + l \right\}.$$

The term $\frac{T}{\pi} e \frac{i}{a}$ is a constant factor dependent on the galvanometer, T being expressed in seconds and i in ampères. As to a, if D is the distance from the mirror to the scale, and d the deflection, both reckoned in centimètres, then $a = \frac{a}{2D}$, but since $\delta = \frac{d'}{2D}$, $\frac{\delta}{a} = \frac{d'}{d}$, and it is unnecessary to know D. The term within the bracket depends on g, the resistance of the whole galvanometer circuit which is determined once for all; the several resistances, R, R′, l, and s, are all known in ohms.

The deflection δ has, of course, to be observed each time; it is to be expressed in the same units as a and I, the strength of the current, which is reckoned in ampères.

The value of L is then finally expressed in terms of T, reckoned in seconds, and of a resistance in ohms. Hence L is determined in the practical system of units, *i.e.*, in 10^9 centimètres, since its dimensions are those of a length.

The accuracy of the formula has been determined by experiments described in the original article, which also contains details of some particular cases.

P. H. LEDEBOER.—RELATION BETWEEN THE COEFFICIENT OF SELF-INDUCTION AND THE MAGNETIC ACTION OF AN ELECTRO-MAGNET.

(*La Lumière Electrique, Vol* 21, 1816, *pp.* 51-70 *and* 112-113.)

In a system made up of bobbins containing soft iron cores, there is a simple relation between the coefficient of self-induction and the magnetic state. In fact, in such a system the increase of induction corresponds with an increase of the magnetic force. Now the increase of the magnetic force is the product of the intensity of the magnetic field by the surface, and the increase of the induction is equal to the product of the coefficient of self-induction by the strength of the current. It follows that this latter product is proportional to the magnetic field, so long as the lines of force do not change their position. Generally, the distribution of the lines of force varies slightly in a system of bobbins containing iron, and the author has therefore sought to determine experimentally how far the proportionality between the magnetic field and the product of the coefficient of self-induction by the intensity of the current in the bobbins holds good.

With this object in view determinations were made simultaneously of the magnetic moment and the coefficient of self-induction of a bobbin containing a soft iron core. The magnetic moment was determined by the method of Gauss, by means of a dead-beat magnetometer of Weber, and the coefficient of self-induction by the method described in the preceding abstract. On examin-

ing the curves plotted from the results, it appears that, in the case of a bobbin without a core, the magnetic moment as well as the extra current are represented by straight lines, which agrees with the theory; the coefficient of self-induction, being constant, is represented by a straight line parallel to the X-axis. In the case of the bobbin with an iron core, the course of the curves is quite similar and they coincide if the ordinates are reduced in a certain ratio. Here, therefore, there is complete proportionality between the two effects.

A number of experiments on dynamos, both of the Siemens and Gramme type, also tend to support the theory, though the proportion does not hold quite so strictly.

P. H. LEDEBOER—MEASUREMENT OF THE INTENSITY OF A MAGNETIC FIELD.

(*La Lumière Electrique*, *Vol.* 21, 1886, *pp.* 342-350.)

There are two cases which may occur—that of a weak but uniform field, such as that of the earth, or that of a strong but variable field, as in a dynamo machine. The methods used for the measurement of the former are well-known, and it is more especially with the measurement of the latter that the author occupies himself. The most convenient unit of measure is the C.G.S. unit, as we then have the intensity of the earth's magnetism expressed by the number 0·2, while that for a dynamo may be from 5,000 to 10,000.

The method is that of Weber, such as it was used for the determination of the value of the ohm. A small coil is rotated through an angle of 180°, and the deflection of a ballistic galvanometer produced by the induced current is observed; from which we can calculate the value of the magnetic field, or this deflection can be compared with that produced by the discharge of a condenser which has been charged to a known potential. In order to carry out this experiment the exact surface of the coil must be known, and it must be turned through exactly 180°, which is somewhat difficult, but may be fairly successfully accomplished by placing a stop at the right position.

The above method of rotating a small coil is however rarely applicable to the determination of the magnetic field of a dynamo, as there is no room for the coil between the electro-magnets and the armature; but by a slight modification it becomes applicable. Instead of a coil of some size, a flat spiral is used, and, instead of rotating it, the magnetic field is suddenly reduced to zero by interrupting the current. If S is the total surface of the coil perpendicular to the lines of force, F the intensity of the magnetic field, r the resistance of the flat coil, g that of the galvanometer, and r^1 that of an auxiliary resistance in circuit with the coil and the galvanometer, we have the quantity of electricity, q, passing through the galvanometer, which may conveniently be one of Deprez-d'Arsonval's.

$$q = \frac{F\,S}{g + r + r^1}.$$

The quantity, q, may either be measured by the throw of the galvanometer, in which case its constant K comes into the equation, or we may compare it

with a microfarad condenser. The article concludes with a numerical application of the method to a Gramme dynamo, of which the intensity of the magnetic field was 2,850 units (C.G.S.) for a current of 25·5 ampères, and 409 units for 2·5 ampères.

VASCHY and DE LA TOUANNE—COEFFICIENTS OF INDUCTION OF TELEPHONIC AND TELEGRAPHIC APPARATUS.

(*Bull. de la Soc. Internationale des Electriciens, Vol.* 3, *No.* 29, *July*, 1886, *pp.* 242-254.)

With the very quick working instruments now in use the current never has time to attain its permanent phase, and the apparatus really do their work during the variable period of the current; consequently the determination of the coefficient of induction of the coils used in the instruments is one of great importance. Moreover, the best arrangement of the battery in general may not be the best in cases where very short emissions to line are made. Self-induction also plays an important part where the line is struck by lightning, for owing to the suddenness of the discharge, the self-induction may be so great as to oppose a higher resistance than the silk covering of the wires.

It might be imagined, therefore, that self-induction was always harmful, but there are cases where it is a positive advantage. The most striking instance of this is with the Delany system of multiplex telegraphy.

For determining the coefficients, the authors made use of two methods—the Wheatstone bridge and the differential galvanometer—for the coefficient of self-induction, and of a special zero method for the measurement of the coefficient of mutual induction.

In the differential galvanometer method the one circuit comprised the experimental coil (L), a fixed resistance without induction (r) to the terminals of which were attached the electrodes of a condenser (C), and the one coil of the galvanometer; the second circuit, besides the other coil of the galvanometer, comprised a variable resistance (R); a shunted battery provided with a key, and a stretched wire with a movable contact joined up to the one pole of the battery, formed the part common to both circuits. On depressing the key an approximate balance was obtained by altering the variable resistance; the shunt is then removed from the battery, and a final delicate adjustment is secured by shifting the contact along the stretched wire. The needle having been brought to zero, the key is let up and the deflection d is noted. The condenser C is then replaced by one of different capacity, C^1, and a new deflection, d^1, is noted. We have then

$$\frac{L - C\,r^2}{d} = \frac{L - C^1\,r^2}{d^1}$$

or

$$L = \frac{C^1\,d - C\,d^1}{d - d^1} \times r^2.$$

The Wheatstone bridge arrangement is precisely similar in principle

One arm contains the coil L, the resistance r, with the condenser C; the other arms contain the usual resistances. The galvanometer is in one diagonal, with a contact sliding on a stretched wire, and the battery and key are in the other diagonal. The method and the equation are the same as for the differential galvanometer.

For the measurement of the coefficient of mutual induction two circuits are joined up, the one containing the primary coil, the battery, a resistance R_1, and a key; the other the secondary coil, a galvanometer, and a resistance R_2. The ends A_1 A_2 of the resistances R_1 and R_2 are joined up, and the ends B_1 B_2, and in the connection A_1 A_2 a condenser is inserted. On completing the primary circuit the galvanometer shows a deflection d, partly due to the induced current, partly to the charge of the condenser. Replacing the condenser by one of different capacity and repeating the experiment, another deflection, d^1, is obtained; then

$$M = \frac{C^1 d - C d^1}{d - d^1} \times R_1 R_2.$$

The following table contains a selection from the values found for various instruments:—

Instrument.	Resistance.	Coefficient of self-induction.	Coefficient of mutual induction.
Electro-magnet for Van Rysselberghe's apparatus	Ohms. 505	6·02	...
Do. do. do.	500	7·27	...
Electro-magnet of Morse apparatus—			
Bobbin I., without core	242	0·233	...
Do. II., do.	242	0·265	...
Do. I., with core	242	1·66	...
Do. II., do.	242	1·71	...
Two bobbins in series	484	6·37	...
Do. with armature	484	10·68	...
Annunciator Sieur	179	0·915	...
D'Arsonval telephone	219	0·15	...
Siemens telephone	227	0·17	...
Ader telephone (small)	83	0·033	...
Do. do. (large)	50	0·021	...
Induction coil for telephonic exchange ...	200 0	1·105 0	0·14
Do. for D'Arsonval microphone	150 1·5	0·42 0·0067	0·05

Dr. L. WEBER—DANGER OF LIGHTNING AND CONSTRUCTION OF LIGHTNING CONDUCTORS.

(*Journal Télégraphique, Vol.* 10, *Nos.* 6 *to* 9, *pp.* 124, 147, 168, 196.)

In passing from a cloud at a different potential to the earth, the lightning strikes the more elevated and better conducting portions of the earth. The construction of buildings or the nature of the ground on which they are built may contribute to an electric discharge. Since the discharge will naturally follow the path of least resistance, the nature of the building and of the soil is also of much importance in this respect. Sometimes the discharge divides—*e.g.*, part may go to earth through the lightning rod and part through the water-pipes. It has not yet been definitely settled if the variations in the duration of a discharge depend on phenomena occurring in the cloud itself, or if they are due to the degree of conductivity of the bodies through which the discharge takes place.

The importance of efficient protection from lightning may be seen from the fact that in Germany alone the number of cases of accident from lightning have tripled in the thirty years from 1850 to 1880.

Various conditions may affect the gravity of the danger. The general configuration of the country is of importance, for more accidents happen in plains than in mountainous districts. In the latter, the houses, being mostly built in the valleys, are protected by the neighbouring peaks. Any elevation of the ground, as well as the proximity of masses of water above or below ground, add to the risks, while they are diminished by the presence of forests. The liability to accident increases with the height of the buildings, as is apparent on noting the ratio of accidents to churches, windmills, and other lofty buildings. Scattered buildings, as in rural districts, are more exposed than blocks of buildings in towns. Buildings in the construction of which large masses of metal are used are more liable to be struck by lightning than other buildings constructed of non-conducting materials. The proximity of lofty trees and of telegraph and telephone poles and wires is also a source of danger.

Numerous scientific experiments and a century of experience have proved that a building may be entirely protected by the use of a lightning-rod. The three parts of a lightning-rod, viz., the earth, the conductor, and the pointed rod, must form one complete whole. The point should be higher than any portion of the building to be protected, the conductor should be connected to all metallic masses in the building, and the earth should be unexceptional.

There are two principal systems for the construction of lightning-rods: the one that of Gay-Lussac, in which a few points and a few conductors of large size are used; and that of Melsens, who recommends a great number of points and of conductors of relatively small size, which are, however, all metallically connected together, so that the building is, as it were, enclosed in a metallic cage. Which of the two systems is the better has not yet been definitely settled, but certainly Gay-Lussac's plan, if properly carried out, gives always excellent results. The great objection is that the discharge may

take place through some by-path, such as the gas or water pipes or damp walls. This may, however, be got over by installing several branch lines to the earth. When, however, a good earth cannot readily be obtained, it is perhaps better to adopt Melsens' divided system.

In fixing up a system of lightning-rods, care should be taken that the conductor is connected directly to any metallic or damp bodies which might serve as a by-path for the lightning. The points should be from 6 to 12 feet high, and should be so arranged that every part of the building is within the zone of protection. The conductors should be as short as possible, and when there are several they should all be connected together by a horizontal conductor running round the roof.

E. COHN and L. ARONS—COEFFICIENTS OF CONDUCTIVITY AND SPECIFIC INDUCTIVE CAPACITY.

(*Annalen der Physik und Chemie, Vol.* 28, *Pt.* 3, *No.* 7, 1886, *pp.* 454-477.)

All insulators or dielectrics are in some degree conductors, and it is desirable to study the behaviour of various substances in which both induction and conduction are produced simultaneously by the action of electro-motive force. In a homogeneous and isotropic medium bounded by the two surfaces of the electrodes, the lines of conduction and of electric displacement or induction coincide, and the total current is the algebraical sum of both components, the ratio of which depends only on the change-rate of the current and on the constants λ (specific conductivity) and μ (specific inductive capacity).

If this view is in accordance with experience, such a body can be replaced in any circuit by two bodies, one of which has the galvanic resistance of the original body but no capacity, while the other has an infinite resistance and the capacity of the given body. The two constants λ and μ can then be separated from each other and measured, by altering at one time the capacity and at another the resistance.

In the circuit of a battery was arranged a system comprising a finite resistance without capacity, and a condenser of infinite resistance, the two being parallel; one electrode of a quadrant electrometer was connected to one terminal of the system, the other electrode to one pole of the battery and to earth.

In order to avoid any effects due to residual charge of the condenser, the experiments were carried out with liquid dielectrics, the substances used being pure xylene, aniline dissolved in xylene in varying proportions, aniline dissolved in benzine, Canada balsam dissolved in benzine and castor oil.

The system could consist of—

(*a*) The liquid under experiment, *i.e.*, a dielectric having some degree of conductivity.

In this case the capacity (C) $= c_f$, and the resistance (R) $= e$.

(*b*) The liquid and an air-condenser of capacity C_1

$$C = c_f + c_1, R = e.$$

(*c*) The liquid and a resistance joined up parallel

$$C = c_f,\ R = \frac{e\,r}{e + r}$$

(*d*) The liquid, air-condenser, and resistance

$$C = c_f + c_1,\ R = \frac{e\,r}{e + r}$$

(*e*) The air-condenser and resistance without the liquid

$$C = c_1,\ R = r.$$

(*f*) The resistance only

$$C = o,\ R = r.$$

Each of the above combinations leads to an equation of the form

$$(C + y)\ R = \frac{t}{\log. \frac{E}{E - \omega}}$$

where E is the electro-motive force of the battery, and ω is the potential of the pair of quadrants in direct connection with the system; and the whole six equations must be satisfied by the same values of c_f and e.

It results from the experiments that, for the four liquids experimented upon, of very different conductivity, the occurrence of the variable current may be represented by the simultaneous and independent existence of a galvanic conduction and the formation of a dielectric polarisation; and the quantity which in this representation appears as a resistance is identical with the resistance, which is defined by measurements with steady currents.

The following table shows the ultimate values arrived at for the dielectric coefficient (specific inductive capacity), μ, referred to air, and the specific conductivity, λ, referred to mercury :—

SUBSTANCE.	μ.	λ.
Pure xylene	2·23	$<6{\cdot}3 \times 10^{-17}$
Aniline in xylene, No. 1 ...	2·39	$5{\cdot}34 \times 10^{-15}$
" " " " 2 ...	2·71	$7{\cdot}26 \times 10^{-14}$
" " " " 3 ...	3·09	$4{\cdot}46 \times 10^{-13}$
Aniline in benzine	2·82	$1{\cdot}60 \times 10^{-13}$
Canada balsam in benzine...	2·79	$1{\cdot}83 \times 10^{-13}$
Castor oil...	4·43	$7{\cdot}7 \times 10^{-17}$

A glance at these figures shows at once, that whilst the conductivity of xylene is increased ten thousand times by the successive addition of aniline, the specific inductive capacity only increases by about one-third of its value.

The specific inductive capacity increases with the conductivity, but very much more slowly; except in the case of the Canada balsam and the castor oil, which is the worst conductor next to the pure xylene, and yet has by far the highest specific inductive capacity of all the liquids experimented upon. The coefficients of conductivity and specific inductive capacities do not mutually determine each other.

It was to be expected that the case of xylene would confirm Maxwell's theory that the dielectric capacity of a transparent medium should be equal to the square of its index of refraction, which corresponds to waves of infinite length. The index of refraction of xylene for infinite wave lengths, as calculated from measurements of the hydrogen lines, was found to be 1·472 and 1·471; while the square root of the dielectric capacity is 1·49 ($\sqrt{2 \cdot 23}$).

This relation had not been determined for the fatty oils. Hopkinson found the index of refraction for castor oil to be 1·467, whilst his determination of the square root of the specific inductive capacity is 2·186, and the author's 2·10; the difference, therefore, is not occasioned by the conduction of the castor oil.

It is possible that in other cases, where a difference exists between the values found for the electrical and optical constants, that more accurate experiments may rectify the value of the specific inductive capacity, which generally comes out too high.

G. QUINCKE—PROPERTIES OF DIELECTRIC FLUIDS.

(*Annalen der Physik und Chemie, Vol.* 28, *Pt.* 4, *No.* 8, 1886, *pp.* 529-550.)

The experiments were made partly by means of the electric balance, which consists essentially of a plate condenser, the upper plate of which is hung from one end of the beam of a balance, the lower plate being to earth. The specific inductive capacity of the dielectric can then be determined by weighing the electric attraction of the two plates parallel to the lines of force. It is essential that the two plates should be accurately parallel, and this was accomplished by having a spirit level attached to the suspended plate, which could thus be levelled by slackening or tightening its suspension on one side or the other; the bottom fixed plate was then levelled up to the suspended one by means of set screws.

For experimenting with fluids the condenser could be placed in a vessel containing the liquid, due allowance being made for its specific gravity, and great care being taken to ensure efficient insulation. The specific inductive capacities were also measured by the discharge of the condenser through a galvanometer.

Experiments were made on the distance through which a spark discharge would take place, a special form of discharger being used, which could contain the liquid in which the two electrodes were immersed. The necessary potential was obtained by means of a Holtz machine and a battery of Leyden jars.

The author has also investigated the specific conductivity of the various fluid dielectrics on which he experimented.

For large electric forces the dielectric coefficients of a liquid are found to be slightly smaller than for small electric forces: this is so whether the

measurements were made with the electric balance or with the condenser discharge.

The dielectric constant of a liquid comes out from ten to fifty per cent. higher with the balance than with the condenser. The difference of the two determinators is generally greater, the greater the coefficient.

In different dielectric liquids the length of the spark discharge is different for the same difference of potential, but it is always much smaller than in air.

The difference of potential necessary for producing sparks within a dielectric liquid increases with the length of the discharge, but more slowly.

The electric pressure in the dielectric liquids on the passage of the spark is less for greater lengths of discharge than for smaller lengths. It varied with the liquids tested between 0·04 and 0·25 atmospheres for a length of discharge of one millimètre.

The intensity af a constant electric current in a dielectric liquid increases more rapidly than the electro-motive force producing it. Ohm's law no longer holds good for these dielectrics.

Some phenomena point to an electrolytic decomposition of the dielectric liquid, as soon as the electric force in the liquid between the two electrodes passes a certain value, which differs for various liquids.

E. EDLUND—ELECTRO-MOTIVE FORCE OF THE ELECTRIC SPARK.

(*Annalen de Physik und Chemie, Vol.* 28, *Pt.* 4, *No.* 8, 1886, *pp.* 560-573.)

A statical plate machine was connected up to a galvanometer provided with a shunt of suitable resistance, and parallel with the shunted galvanometer was arranged another shunt circuit comprising a vessel which could be exhausted of air, and into which projected two wires terminating in ball electrodes. When the plate machine was worked at a certain speed, and the last-named circuit was open, the galvanometer showed a deflection of 1 or 1½ divisions; but if the shunt circuit was closed so that the current from the plate machine divided itself between the vacuous space, the galvanometer shunt, and the galvanometer itself, instead of the deflection being diminished, it increased to 50 divisions.

This can only be explained by the supposition that there exists in the electric spark an E.M.F. which sends a current in the opposite direction to that from the plate machine. Experimenting with tubes provided, one with brass electrodes and the other with aluminium electrodes, it was found that the deflection of the galvanometer varied with the pressure in the tubes, and that it was a minimum at 6 mm. pressure for the brass electrodes, and between 30 and 70 mm. for the aluminium.

An induction coil was tried instead of a plate machine, with similar results. The difference of strength of the currents which prevails for various pressures depends on the modifications of the E.M.F. of the spark, and cannot be explained by alterations of resistance alone.

In order to see which electrode, the positive or the negative, was the seat

of this E.M.F., a tube was arranged in form of a Y, with an electrode at the end of each branch; the tube could be put in communication with an air-pump. Calling the left-hand top electrode A, the bottom one B, and the right top one C, the distance of A from B was greater than that of C from B. A battery was connected up between A and B, and a shunted galvanometer and a resistance of 28,000 ohms between C and B. If B is made the positive pole, there will be an opposing similar force at C, and it is the difference of the two forces which will produce a current through the galvanometer. If B is the negative electrode, the current is in the opposite direction.

If b is the force at B, and c at C, then, if the strength of the current decreases when the rarefaction increases, b must decrease more rapidly than $b - c$, and conversely. Consequently the force b rises and falls through wider limits than the difference $b - c$. With a pressure of 23·2 mm. when B was positive, there was a deflection of 3·3 divisions; when B was negative, 1·3 division. With a pressure of 0·023 mm. when B was positive, there was a deflection of 1·8 divisions; when negative, 20·2 divisions: the E.M F. in both cases was acting in opposite direction to the charge. On charging, an opposed electro motive force is produced both on the positive and on the negative electrode; that on the positive plate decreases with increase of rarefaction, that on the negative increases.

The early experiments were made with aluminium electrodes, but these were afterwards replaced by other metals, when it was found that the E.M.F. depended on the nature of the electrode as well as on its size and form.

At every charge two induced currents were set up in the galvanometer coils, but these nullified each other by passing through the shunt, and were without effect on the results.

The effect of magnetism was very marked on the pole C; it increases the deflection when the pressure is less than 0·054 mm., and decreases it for higher pressures. The effect on the electrode B is the opposite; for pressures less than 0·041 it diminishes the current. If the magnet was at an intermediate position between B and C, it always diminished the current.

The experiments also explain the fact that in the case of an arc lamp under ordinary atmospheric pressure the positive carbon is hotter than the negative, while in rarefied air the reverse is the case. In the former case the positive carbon is the seat of the highest E.M.F., in the latter the negative.

WYBAMO—PHOTOMETER FOR ELECTRIC LIGHT.

(*Beiblätter, Vol.* 10, *No.* 5, 1886, *p.* 289. *Dingler's Journal*, 258, *p.* 69.)

The photometer depends on the principle that the two surfaces to be compared, each of which is at a different distance from the source of light, are illuminated, and that so much light from the standard flame is allowed to fall on to the more distant and therefore less brightly illuminated surface as will bring its brightness up to that of the nearer surface.

NOACK—VOLTA'S FUNDAMENTAL EXPERIMENT.

(*Beiblätter, Vol.* 10, *No.* 5, 1886, *p.* 292. *Zeitschrift für Förderung des Phys. Unterrichts*, 2, *p.* 177.)

The reproduction before a class or audience of Volta's fundamental experiment is difficult, and the author recommends for the purpose one of Bohnenberg-Fisher's electroscopes, in conjunction with a projection lantern. The conductivity of the dry pile may be improved by replacing the gold leaf on the back of the silver paper by peroxide of manganese, with which a small quantity of calcium chloride has been mixed.

A. BENECKE—AMPERÈS STAND.

(*Beiblätter, Vol.* 10, *No.* 5, 1886, *p.* 293. *Zeitschrift für Forderung des Phys. Unterrichts*, 2, *p.* 181.)

As foot, the author uses a zinc tripod with levelling screws, into which is fixed a brass rod having a steel point at its extremity. A wooden vessel with two concentric channels for the mercury can be clamped to the standard, and is provided with terminals; the movable coils are a rectangle, astatic conductor and a coil.

H. ARON—INDUCTIONLESS COILS FOR ELECTRO-MAGNETS.

(*Beiblätter, Vol.* 10, *No.* 5, 1886, *p.* 294. *Polytecha. Notizblatt*, 41, *p.* 35.)

Between the several layers of wire were interposed layers of lead, copper, or tinfoil, which formed closed circuits; or layers of bare copper wire were wound on between the insulated wires. The frame on which the wires were wound was also made of thick copper sheet forming a closed circuit. The induction currents set up on opening the circuit were thereby much diminished.

A. RIGHI — EXPERIMENTAL AND THEORETICAL RESEARCHES ON THE REFLECTION OF POLARISED LIGHT FROM THE POLE OF A MAGNET.

(*Beiblätter, Vol.* 10, *No.* 5, 1886, *p.* 294. *Real Accadinna dei Lincei*, 282, *p.* 367.)

With light falling perpendicularly on the magnet, there was obtained a double rotation of 37 minutes, in an opposite direction to that of Ampère's molecular currents. It could not be definitely settled if an elliptical polarisation took place. If the incident light strikes the surface at an angle, and the undulations are parallel to the plane of incidence, the light can almost be extinguished by turning the analiser, and the phenomenon is one of simple rotation, always in the opposite direction to that of the current. As a matter of fact it is a case of elliptical polarisation of very great eccentricity.

If the undulations are at right angles to the plane of incidence, there is

elliptical polarisation, the eccentricity of which decreases with the angle of incidence; the direction of rotation is always the same. The author has also experimented on light reflected several times backwards and forwards from the poles of magnets. He next examines Fitzgerald's theory, and shows that his experiments do not confirm it. His own theory is that in consequence of the magnetisation the iron behaves towards the waves of light, not only according to their position with respect to the plane of incidence, but also according to the direction, in which the particle under consideration follows its path. This new theory holds the same relation to ordinary metallic reflection that the elliptical double refraction of quartz, as put forward by Airy, does to the ordinary theory of double refraction.

H. GÖTZ and A. KURZ—GALVANIC RESISTANCE OF WIRES FOR VARYING STRAINS.

(*Beiblätter, Vol.* 10, *No.* 6, 1886, *p.* 364. *Repert. der Physik*, 21, *p.* 683.)

If s is the ratio of the contraction in cross-section to the elongation, q the cross-section, Δp the increase in the load, k the specific conductivity, then

$$z = 10^5 \frac{q \, \Delta k}{k \, \Delta p};$$

and for the decrease of Δk with increase of Δp, we have—

Steel wire, annealed,	$q = 1 \cdot 2$,	$z = 10 - 16\,s$,	$s = \frac{1}{3} \cdot 3$
„ „	$= 0 \cdot 61$,	$= 16 - 14\,s$,	$= \frac{1}{3} \cdot 3$
„ hard,	$= 0 \cdot 61$,	$= 13 - 12\,s$,	—
„ glass hard,	$= 0 \cdot 61$,	$= 11 - 12\,s$,	—
Copper wire, soft,	$= 2 \cdot 8$,	$= 18 - 21\,s$,	$= \frac{1}{3}$
„ hard,	$= 2 \cdot 8$,	$= 11 - 21\,s$,	$= \frac{1}{4}$

W. OSTWALD—THE INFLUENCE OF THE COMPOSITION AND CONSTITUTION OF ACIDS ON THEIR ELECTRICAL CONDUCTIVITY.

(*Beiblätter, Vol.* 10, *No.* 6, 1886, *p.* 364. *Journal für Prakt. Chemie*, 32, *p.* 300.)

Following the method of Kohlrausch, the author has investigated the conductivity of a large number (117) of acids in various degrees of dilution from 2 to 4,096 litres per gramme—molecular weight at 25° C.

The monobasic haloid acids have very high values, with the exception of hydrofluoric acid. Prussic acid is almost a non-conductor; sulphocyanic acid is, on the contrary, a fair conductor; and hydroferrocyanic acid is still better.

Nitric, chloric, perchloric, and bromic acids are about equal to each other and to the haloid acids; iodic acid has not so a high a value. The three acids containing phosphorus show that the conductivity decreases with an increase in the amount of oxygen in the acid. The acids containing sulphur or selenium, on the contrary, increase in conductivity with the amount of oxygen.

The acids of the acetic series of monobasic acids diminish in conductivity for an increase in carbon up to propionic acid, after which the conductivity is fairly constant. The haloid substitution products of acetic acid conduct better the greater the amount of the halogen contained. In the lactic series of monobasic acids, the hydroxyl acts in a similar way. The acids of the oxalic series for an increase in the percentage of carbon show a considerable decrease of conductivity. The aromatic series does not exhibit any regular behaviour. Unsaturated acids are regularly better conductors than the corresponding saturated acids.

Some amides were also tested, and were found to be poor conductors.

L. PILLEUR and E. JANNETAZ—THERMO-ELECTRIC EXPERIMENTS.

(*Beiblätter, Vol.* 10, *No.* 6, 1886, *p.* 370. *Journal de Physique,* 5, *p.* 172.)

An irregular structure can be imparted to a piece of zinc, tin, iron, or copper by rolling. If the plate thus formed is heated at the centre, and two points, B and C, are connected with a galvanometer, C being in the direction of the rolling from the heated point, and B at right angles to it, the current flows from B to C in the outer circuit. The thermo-electro-motive force increases if the rolling is repeated in the same direction.

E. VON AUBEL—INFLUENCE OF MAGNETISM ON THE POLARISATION OF DIELECTRICS.

(*Beiblätter, Vol.* 10, *No.* 6, 1886, *p.* 371. *Bull. de l'Academie Roy. de Bruxelles,* 10, *p.* 609.)

According to Rowland, Hall's phenomenon and the electro-magnetic rotation of the polarisation plane must depend on the same principle, and hence Hall's phenomenon should occur in dielectrics, and magnetism must influence their dielectric polarisation. Lorentz, on the other hand, has shown that Hall's phenomenon does not occur in dielectrics.

The author's experiment, made with plates of sulphur and with two parallel copper plates between which was the dielectric, these plates being placed between the poles of a powerful electro-magnet, all showed that magnetism has no effect on the dielectric; as has been noticed by Hall himself.

P. CARDANI—ALTERATION OF THE DIAMETER OF THE SPARK DISCHARGE WITH ALTERATION OF THE POTENTIAL AND RESISTANCE.

(*Beiblätter, Vol.* 10, *No.* 6, 1886, *p.* 374. *Giornale di Scienze Naturali ed Economiche, Palermo, Aug.,* 1885.)

The spark discharges took place between two platinum-coated spheres of 40 mm. diameter, and were photographed on glass, the photographs being

subsequently measured with a cathetometer. It was found that for distances of 2 to 16 mm. the diameter of the spark increases as the square root of the potential, and decreases according to a hyperbolic function with an increase of the resistance, so that for a considerable resistance it becomes practically constant. If y is the diameter of the spark, x the resistance, and a, c, and h constants,

$$y = h + \frac{c}{a + x}.$$

P. CARDANI—THE SECOND LAW OF HARRIS.

Beiblätter, *Vol.* 10, *No.* 6, 1886, *p.* 275. *Giornale di Scienze Naturali ed Economiche, Palermo, Dec.*, 1885.)

The author has carried out a series of experiments, with a Holtz machine and a battery of Leyden jars, on the length of the spark discharge in rarefied air. If D is the deflection of the electrometer, H the pressure, L the length of (the spark, then for $L = 15$ mm. the quotient $\frac{\sqrt{D}}{H}$ increases with decrease of the pressure. At constant potential L is nearly inversely proportional to H within certain limits. When L was altered from 5 to 100 mm., and H from 86 to 688 mm., the alteration of the potential for each individual L was the same for increase of pressure. In the same way for each pressure the alteration of the potential with increasing L was the same.

J. BERNSTEIN—ON THE TEMPORARY APPEARANCE OF ELECTRIC POLARISATION.

(*Beiblätter*, *Vol.* 10, *No.* 7, 1886, *p.* 419. *Naturwiss. Rundschau*, 1, *p.* 9.)

The battery current was periodically passed through dilute sulphuric acid, and in the intervals the polarisation current was passed through a shunt. A portion of the current was also shunted through a galvanometer. On closing the circuit, the current in the first moment increases exceedingly quickly to a maximum, which probably corresponds to the current without polarisation, and then sinks with decreasing rapidity to a constant value.

G. H. VON WYSS—AN EXPERIMENTAL METHOD OF DETERMINING THE SELF-INDUCTION OF A COIL.

(*Beiblätter*, *Vol.* 10, *No.* 7, 1886, *p.* 420. *Dissert. Zurich*, 1886.)

The primary circuit comprises an alternate-current machine and a coil, the coefficient of self-induction of which is known; the secondary circuit contains the coil whose coefficient is to be determined. The equations are—

$$R_1 I_1 = E - \frac{P\, d I_2}{dt} - \frac{Q_1\, d I_1}{dt}$$

$$\text{and } R_2 I_2 = \quad - \frac{P\, d I_1}{dt} - \frac{Q_2\, d I_2}{dt}$$

where E is the electro-motive force, P the mutual induction, I_1 and I_2 the currents, R_1 and R_2 the resistances, and Q_1 and Q_2 the self-induction of primary and secondary respectively. The two currents are measured by an electro-dynamometer, which is either without practical self-induction, or of which the self-induction is known. First the current I_2 is passed through both coils of the electro-dynamometer, and secondly only through the swinging coil, the current I_1 passing through the fixed coil. The experiments have proved the accuracy of the method.

T. GROSS—A NEW METHOD OF PRODUCING ELECTRIC CURRENTS BY MAGNETISM.

(*Beiblätter, Vol.* 10, *No.* 7, 1866, *p.* 425. *Wien. Bericht*, 92, *p.* 1378.)

The currents are produced by the action of electro-magnets on solutions of various iron salts, such as the chloride and sulphate. They are probably due to the dissolving of the magnetised pole and the reduction of the salt in solution.

F. WÄCHTER—DISCRIMINATION OF POSITIVE AND NEGATIVE ELECTRICITY.

(*Beiblätter, Vol.* 10, *No.* 7, 1886, *p.* 427. *Wien. Anzieger*, 2, *p.* 5.)

In conductors of high specific resistance the mean of the potential value at the ends lies the nearer to the negative electrode the greater the resistance. For accumulations of equal quantities of electricity on equal conductors, the potential measured by the electrometer is greater for the positive charge than for the negative charge; this does not depend on unequal losses of electricity to the air, but on unsymmetrical arrangement of the potential surfaces for positive and negative electricity. The unequal striking distance between differently formed electrodes gives a proof that the losses of electricity do not postulate this difference. The rotation of the electric orrery in the direction of the positive electric stream lines shows that the motions of the air at the positive electrode are of a different nature from those at the negative, and the dissymmetry of the equipotential lines follows from the dissimilar forms of the positive and negative brush discharge.

L. PALMIERI—ON THE ELECTRICITY PRODUCED BY FLAMES.

(*Beiblätter, Vol.* 10, *No.* 7, 1886, *p.* 429. *Nuovo Cimento*, 19, *p.* 36.)

The author concludes from his experiments with flames from various combustible bodies that electricity is developed on the combination of two simple bodies; that bodies which appear as electro-negative on electrolysis, develop positive electricity on synthesis and conversely; that the negative electricity obtained by dipping zinc in sulphuric acid may be derived from the electro-positive zinc itself, without its being in contact with the oxygen in the water.

P. LANGER—ABSORPTION OF LIGHT IN ELECTRIC CONDUCTING MEDIA.

(*Beiblätter, Vol.* 10, *No.* 7, 1886, *p.* 432.)

The increase of the conductivity of a body is connected with a decrease of the velocity of propagation of the light waves, but this latter means a decrease of the oscillations, that is, of the brilliancy, especially for refrangible rays. For white light, it would become reddish. The experiment made with gold leaf on a glass tube did not at all confirm this view, though possibly the course of the phenomenon may have been altogether altered by the fusing of the gold on to the glass.

J. W. GILTAY—DECOMPOSITION OF WATER BY A HAND DYNAMO MACHINE.

(*Beiblätter, Vol.* 10, *No.* 7, 1886, *p.* 435. *Maandblad voor Natuurwetensch,* 13, *p.* 1.)

A small hand Gramme series dynamo was connected up to a voltameter, but however quickly it was rotated no electrolysis took place until the electrodes of the voltameter were connected by a resistance of a few ohms, or short-circuited by a piece of wire. The reason is that in the first instance the difference of potential at the terminals of the voltameter was less than 1·14 volt, too little to send any current through the circuit, and the field-magnets of the dynamo were therefore unexcited; as soon as a by-pass was provided, part of the current flowed through it, and the field-magnets being excited, the difference of potential rose above 1·14 volt and electrolysis commenced. If now the by-pass was interrupted and the dynamo still worked, the current passed entirely through the voltameter, but as soon as the speed was at all slackened the current ceased, and it was impossible to start it again without reconnecting the by-pass.

J. W. GILTAY--USE OF AN AUXILIARY BATTERY FOR TELEPHONY.

(*Beiblätter, Vol.* 10, *No,* 7, 1886, *p.* 437. *Archiv. Néerland,* 20, *p.* 117.)

A condenser is used, consisting of a middle plate, A, connected to the secondary circuit, and two outer ones, B and C, B being connected directly to earth, and C through a Zamboni's dry pile. The two outer plates are provided with hearing tubes. With this arrangement only the primary note corresponding to the period of the microphone is heard, and not the higher octaves as is the case in other electric and magnetic telephones.

H. WILD—ON THE RELATIONS BETWEEN THE VARIATIONS OF THE EARTH'S MAGNETISM AND THE PHENOMENA ON THE SUN.

(*Beiblätter, Vol.* 10, *No.* 7, 1886, *p.* 438. *Bull. de l'Acad. de St. Petersburg,* 12, *p.* 329.)

As we do not really know which of the various phenomena occurring in the sun we should couple with magnetic storms, it is very desirable that further observations of the sun should be made, not so much at regular intervals as during magnetic disturbances.

W. PEUKERT—MEAN INTENSITY OF THE MAGNETIC FIELD OF DYNAMOS IN ABSOLUTE MEASURE.

(*Centralblatt, Vol.* 8, *No.* 19, 1886, *pp.* 374-380.)

The intensity of the field depends on the magnetising force, which is proportional to the strength of the current multiplied by the number of turns of wire, and on the magnetic resistance. The intensity of the field of a dynamo may be determined by measuring the current produced when a coil is rotated once in the field. The value thus obtained is, however, not that which exists when the dynamo is at work, for the important action of the helix on the field, which may amount to as much as 25 per cent., is not taken into account.

Experiments were made on a Schuckert dynamo of the type EL_1, the electro-magnets being separately excited, and the difference of potential at the brushes being measured on a torsion galvanometer. Knowing the length of the wire on the armature (l), the circumferential speed of the latter (v), both in centimètres, and the E.M.F. in volts, the intensity of the field is found from the equation

$$F = \frac{E \times 10^8}{l\,v}.$$

Seventeen measurements were made with exciting currents varying from 1 ampère to 20 ampères, the E.M.F. varying from 21 to 88·7 volts, when it was found that the intensity of the field varied from 90 to 400 units. The values calculated from the above formula agreed with the observed values within 8 per cent.

The intensity of the magnetic field may also be expressed by the formula

$$F = \frac{G \cdot \mu \cdot n\,I}{1 + a\,n\,I},$$

where $n\,I$ is the number of ampère-turns, G a constant depending on the shape and form of the electro-magnets, a is a constant depending on the quality of the iron, and μ the coefficient of magnetic permeability. By combining the constant in the above formula, it becomes

$$F = \frac{a\,I}{1 + b\,I}.$$

which is the form given by Frölich.

O. E. MEYER and F. AUERBACH—THEORY OF THE DYNAMO MACHINE.

(*Elecktrotechnische Zeitschrift, Vol.* 7, *June,* 1886, *pp.* 241-244.)

Frölich has shown that his formulæ are applicable to the drum type of dynamo, as made by Siemens and Halske, but it seems desirable to investigate how far they apply to dynamos of the Gramme type. The two conclusions deduced by Frölich are, first, that the current given by any dynamo machine is a function of the ratio of the speed to the resistance; and secondly, that for all practical purposes this function is a linear one.

So far as the first point is concerned, the author's experiments with Gramme dynamos show that the current is not a simple function of the ratio of the speed to the resistance, and that Frölich's formula,

$$I = \frac{M n}{r},$$

must be modified by the introduction of a factor which varies with the speed. Since this factor is not very large, it may perhaps be a linear one, and the formula may more correctly be written

$$I = (1 + a n) \frac{n}{R}.$$

It would appear also that the curve is not a straight line, but is made up of three portions—at first a straight line, then a portion convex to the axis of the abscissæ, and a third portion concave to this axis.

W. KOHLRAUSCH—USE OF SPIRAL SPRINGS IN MEASURING INSTRUMENTS, AND THE EXACTITUDE OF GALVANOMETERS WORKING WITH SPIRAL SPRINGS.

(*Elektrotechnische Zeitschrift, Vol.* 7, *August*, 1886, *pp.* 323-327.)

As springs are now largely used in measuring instruments to oppose the electrical force which has to be measured, it is very desirable to know how far reliance may be placed in them.

A spiral spring belonging to a Jolly's spring-balance has now been regularly experimented upon over a period of seven years, being tested for elongation when stretched by a weight of one gramme, and the results have been concordant throughout that period of time.

The platinum-silver spring of a Siemens torsion galvanometer was twisted through 200°, corresponding to 100 divisions, and left for 70 hours; the permanent set was then only 0·25 of a division. Further experiments of the same kind have been made with steel and German silver springs, with similar results, though the steel came out rather better than the German silver.

Rapid twisting and untwisting over considerable angles of torsion were also without permanent effect.

The influence of temperature is also very slight. Three torsion galvanometers were tried, and it was found that, for each 10 degrees rise of temperature, the readings of the instruments were increased on the average by one-tenth per cent., a quantity which may be neglected for all practical purposes.

It follows, then, that since an error of a half per cent. may always be expected in all electrotechnical measurements, the errors introduced by the use of spiral springs may be left out of account, so long as the limit of elasticity of the spring is not approached.

ANON.—OBSERVATIONS ON STORMS OVER THE GERMAN TELEGRAPH SYSTEM IN 1885.

(*Elektrotechnische Zeitschrift, Vol. 7, September*, 1886, *pp.* 363-370.)

In all, 2,597 observations were made. In the whole year there were 120 days on which thunderstorms occurred, of which 24 were in May, 18 in June, 22 in July, and 19 in August, none in January, and one each in February, November, and December. The greatest number of storms occurred between the hours of 4 and 5 p.m., and the fewest between midnight and 3 a.m. There were 2,911 cases of damage, of which 164 were to indoor instruments, etc., and 1,881 to outdoor parts of the lines; 424 posts were totally damaged, and 1,083 partially damaged, out of a total number of over a million posts. There were 29 cases of fusion or disruption of wires. Out of more than three million insulators, 289 were smashed and 59 were torn out of the poles. Of the 9,662 galvanoscopes in use, 16 were fused and 52 were demagnetised. The instruments which had their coils fused comprised 22 telephones out of 5,458, 30 Morse apparatus out of 9,386, 29 relays, and 1 Hughes apparatus out of 212; 106 lightning dischargers were damaged out of 20,524. From the maps illustrating the article, it appears that the great majority of the storms came from southerly and westerly directions.

Dr. A. Von WALTENHOFEN—THE ACCUMULATORS OF FARBAKY AND SCHENEK.

(*Zeitschrift für Elektrotechnik, Vol.* 4, *No.* 6, *June*, 1886, *pp.* 242-251.)

The experiments were made on a set of 56 cells, each with seven positive and eight negative plates, 55 by 30 cm. square. When the 56 cells were discharged at the rate of 159·5 ampères for 6¼ hours, the E.M.F. fell from 110·4 to 101·5 volts, or 8·07 per cent.; and when at the rate of 160·4 ampères for the same time, the F.M.F. fell from 110·1 to 102 volts, or 7·35 %. On a third occasion the discharge current was 155·2 ampères, and the fall in the E.M.F. at the end of 6¼ hours from 109 to 99·5 volts, or 8·71 per cent. Hence for a mean discharge of 1,000 ampère hours, the loss of potential may be taken at 7·8 per cent.

Subsequently twenty-six of the cells were charged with 1119·21 ampère hours, or 65,090 watt hours, the charge lasting 10½ hours; they were then discharged during 6¼ hours and gave 1026·95 ampère hours, or 57237·68 watt hours; the percentage efficiency was, therefore,

For quantity of electricity	91·75 per cent.
For electrical work	78·71 „

A subsequent experiment gave 90·9 per cent. and 78·5 per cent. respectively. The mean difference of potential of a charged cell was found 2·08 volts, and the internal resistance below one-thousandth of an ohm. Mechanically, the cells gave very good results, being solidly built up, and the oxidisable material not showing any tendency to fall out.

W. PEUKERT and K. ZICKLER—EFFICIENCY OF A ZIPERNOWSKI DÉRI TRANSFORMER.

(*Zeitschrift für Elecktrotechnik, Vol.* 4, *No.* 7, *July* 1886, *pp.* 303-307.)

According to the data of the makers, Ganz & Co., the transformer experimented upon was intended to work with 1,400 watts, with a primary current of 300 volts, and had a coefficient of conversion of $\frac{1}{8}$. The most suitable number of alternations was 100 per second; the resistance of the primary coil was 0·943 ohm, and of the secondary 0·107 ohm. The current was measured both by a Siemens electro-dynamometer and by a calorimeter, the results as given by the two instruments agreeing very closely; and the difference of potential by a Cardew voltmeter. The various parts of the apparatus were connected together by means of wires and suitable mercury cup commutators, so arranged that the several measuring instruments could be inserted in either the primary or the secondary circuit.

The results are given in the following table:—

Primary Current.	Primary E.M.F.	Secondary Current.	Secondary E.M.F.	Work put in.	Work taken out.	Efficiency per cent.	Alternations per second.
2·71	125·5	12·42	24·0	340·105	293·080	87·6	102
3·00	142·5	14·36	26·4	427·500	379·104	88·6	102
4·37	191·3	20·91	35·6	835·806	743·668	88·9	100
4·83	208·9	23·47	39·5	1008·987	927·065	91·8	109

GRASSOT—DIMENSIONS OF LEAD SAFETY FUSES.

(*Zeitschrift für Elektrotechnik, Vol.* 4, *August*, 1886, *pp.* 350-351.)

From the results of a great number of experiments, a series of curves were plotted connecting the diameter of the lead wires with the current they could carry. The experimental curves thus obtained do not differ materially from that derived from calculation.

Let R be the resistance of the lead wire,
I the current,
$2r$ the diameter of the wire,
l the length of the wire,
V the temperature at which lead melts (335° C.),
t the temperature of the surrounding air,
α the specific resistance of lead (20 microhm. cm.),
a a coefficient of cooling,

then, on the supposition that the electric energy furnished by the current is equal to the heat radiated, we have

$$R I^2 = a (V - t) 2 \pi r l;$$

but

$$\frac{\alpha l}{\pi r^2} I^2 = a (V - t) 2 \pi r l,$$

therefore

$$I = \sqrt{\frac{2\,a\,(V-t)\,\pi^2\,r^3}{a}}\,;$$

and if we put

$$K = \pi\sqrt{\frac{2\,a\,(V-t)}{a}},$$

$$I = K\sqrt{r^3}.$$

K may be determined experimentally: for 1 mm. diameter of wire and 11 ampères it is 100. It will be noted that the length of the lead wire does not appear in the final equation.

LIST OF UNABSTRACTED ARTICLES.

(*Philosophical Magazine*, *Vol.* 22, 1886.)

No. 135.—**R. SHIDA**—New Instrument for Continuously Recording the Strength and Direction of a Varying Electric Current. **O. HEAVISIDE**—Self-Induction of Wires. **A. B. BASSET**—Induction of Electric Currents in an Infinite Plane Current-Sheet which is Rotating in a Magnetic Field. **W. EMMOTT and W. ACKROYD**—Electric Light Firedamp Indicator. **A. P. LAURIE**—E.M.F. of Cells having an Aluminium Electrode. **S. P. THOMPSON**—Mode of Maintaining Tuning Forks by Electricity.

No. 136.—**S. BIDWELL**—Magnetic Torsion of Iron and Nickel Wires. **O. HEAVISIDE**—Self-Induction of Wires. **S. P. THOMPSON**—Formulæ of the Electro-Magnet and Equations of the Dynamo. **BOSANQUET**—Law of Similar Electro-Magnets.

(*Nature*, *Vol.* 34, 1886.)

June 10.—**P. G. TAIT**—The Thomson Effect.

June 17.—**J. D. EVERETT**—The Thomson Effect.

September 23.—**Prof. J. BLYTH**—New Form of Current-Weigher for the Absolute Determination of the Strength of a Current (British Association Report).

(*Proceedings of the Royal Society*, 1886.)

May 20.—**SHELFORD BIDWELL**—The Lifting Power of Electro-Magnets and the Magnetisation of Iron.

May 27.—**H. TOMLINSON**—Effect of Magnetisation on the Elasticity and the Internal Friction of Metals. **JOHN BUCHANAN**—A General Theorem in Electrostatic Induction.

(*Electrical Review of New York, Vols. 8 and 9, 1886.*)

No. 17.—Schuyler System of Incandescent Lighting. Electric Light and Water Gas from the same Plant. New Telephone Call Apparatus. Horen's Lightning Arrestor.

No. 19.—Lines and Cables of American Telegraph and Telephone Company.

No. 20.—Switch Boards of American Telegraph and Telephone Company. Transformation of Heat into Electrical Energy.

No. 22.—New Acid Gravity Battery.

No. 25.—Improved Balance Dynamometer for Measuring Power. Phonoplex System of Telegraphy.

No. 26.—Sun Electric Company's Distributor. Professor Hughes's Theory of Magnetism.

No. 1.—Wire Joints.

No. 2.—Professor M. G. Farmer's Apparatus for Direct Determination of Battery Resistance.

(*The Electrician and Electrical Engineer, New York, Vol. 5, 1886.*)

No. 54.—**T. D. LOCKWOOD**—Telephony and the Operation and Functions of the Induction Coil in Transmitters. **A. H. BAUER**—Secondary Batteries for Light and Power. **Prof. W. A. ANTHONY**—Great Tangent Galvanometer of the Cornell University.

No. 55.—**CARL HERING**—Table of the Properties of Copper, Iron, and German Silver Wires, according to the New Standard Gauge. **C. J. van DEPOELE**—Electric Railway at Minneapolis.

No. 56.—**J. G. WHITE**—Heating of Aerial Conductors by Electric Currents. **A. F. DELAFIELD**—Deposition of Copper by Dynamo Machines. **H. W. LEONARD**—Size of Conductors for Incandescent Lighting when Lamps are in Multiple Arc.

No. 57.—**C. R. CROSS** and **W. E. SHEPARD**—Inverse E.M.F. of Voltaic Arc.

(*Scientific American, Vol. 55, 1886.*)

No. 3.—Thermometer with Electric Alarm.

No. 6.—New Electric Organ Movement.

No. 7.—Formation and Fixation of Magnetic Curves.

No. 12.—Daun & Lapp's Long-distance Telephone.

(*Journal of the Franklin Institute, Third Series, Vol. 92, 1886.*)

No. 1.—**Captain O. E. MICHAELIS**—Applications of Electricity to the Development of Marksmanship. Report of Committee on the Phelps Induction Telegraph. Report of Committee on the Cowles Electrical Furnace. Additional Facts concerning the Reis Articulating Telephone.

No. 2.—**Captain O. E. MICHAELIS**—Applications of Electricity to the Development of Marksmanship.

(*Comptes Rendus, Vol.* 102.)

LEDEBOER—Deprez-d'Arsonval Dead-beat Galvanometer. **STIELTJES**—Number of Poles on the Surface of a Magnetic Body. **H. LE CHATELIER**—Thermo-Electricity of Iodide of Silver. **CHAUVIN**—Magnetic Rotary Coefficient in Crystallised Bodies. **MASCART**—Magnetisation. **SEMMOLA**—Sounds produced in Vibrating Strips by Electrostatic Discharges. **SEMMOLA**—Secondary Electrolysis. **E. BOUTY**—Measurement of the Conductivity of Dissolved Potassium Chloride. **VASCHY**—Law of Efficiency Corresponding to the Maximum of Useful Work in an Electric Distribution. **E. BOUTY**—Law of Conductivity of Saline Solutions of Medium Concentration. **LEDEBOER**—Relation between the Coefficient of Self-Induction and the Magnetic Action of an Electro-Magnet. **VASCHY**—Law of Efficiency Corresponding to the Maximum of Useful Work in an Electric Distribution. **H. MOISSAU**—Action of an Electric Current on Anhydrous Hydrofluoric Acid.

Vol. 103.—**E. BOUTY**—Conductivity of Mixtures of Neutral Salts. **A. MILLOT**—Electrolysis of an Ammoniacal Solution with Carbon Electrodes. **BARADEL** — Telephonic Experiments. **BICHAT and BLONDLOT**—Absolute Electrometer for Measurement of Very High Potentials. **G. CABANELLAS**—Definition of the Coefficient of Self-Induction of an Electro-magnetic System.

(*Journal de Physique.*)

Vol. 5. May, 1885.—**HILLAIRET**—Wimshurst Machine. **COLLARDEAU**—Experiments on Induction by Movement.

July, 1886.—**BICHAT and BLONDLOT**—Absolute Electrometer with Continuous Reading.

(*La Lumière Electrique, Vol.* 20, 1886.)

No. 17.—**G. RICHARD**—Details of Construction of Dynamo Machines. **A. GRAY**—Methods of Absolute Measurement. **G. PELLISSIER**—The First Steps of Static Electricity. **J. WETZLER**—Weston's New Measuring Apparatus.

No. 18.—**P. MARCILLAC**—The Siphon Recorder. **J. BOURDIN**—Transmission of Power by Means of Compressed Air. **G. RICHARD**—Some New Telephonic Apparatus. **B. MARINOWITCH** — Aymounet's Battery. **A. FAVARGER**—Electric Clock as a Standard Timekeeper. **Dr. J. PULUJ**—Resistance and Density of Carbon Filaments for Incandescence Lamps. **L. WEISSENBRUCH**—The Future of Electricity on Railways.

No. 19.—**J. BOULANGER**—Analogies between Electricity and Hydro-Dynamics. **G. PLANTÉ**—Practical Instructions for Use of Accumulators. **A. GRAY** — Methods of Absolute Measurement **L. WEISSENBRUCH**—The Future of Electricity on Railways.

No. 20.—**G. RICHARD**—Electric Gas Lighters. **A. GRAY**—Methods of Absolute Measurement. **G. PELLISSIER**—The First Steps of Static Electricity. **L. WEISSENBRUCH**—The Future of Electricity on Railways.

No. 21.—**G. PLANTÉ**—Imitation by High Tension Currents of the Intermittent Effects of Lightning Discharges. **E. DIEUDONNÉ**—Estienne's Telegraph. **P. CLEMENCEAU**—Central Station at Tours. **G. PELLISSIER**—The First Steps of Static Electricity. **L. WEISSENBRUCH**—The Future of Electricity on Railways.

No. 22.—**G. RICHARD**—Details of Construction of Glow Lamps. **W. C. RECHNIEWSKI**—Study of Dynamo Machines. **G. PELLISSIER**—The First Steps of Static Electricity.

No. 23.—**C. RESIO**—Indicator of the Twist of a Driving Shaft when running. **D. DECHARME**—Magnetic Images. **G. RICHARD**—Electric Guns. **E. DIEUDONNÉ**—Central Stations for Electric Lighting.

No. 24.—**G. RICHARD**—American Electric Railways. **C. DECHARME**—Magnetic Images. **L. DE LA ESCOSURA**—Application of Electricity to Metallurgy.

No 25.—**C. DECHARME**—Magnetic Images. **Dr. H. MICHAELIS**—Telephonic Apparatus for Testing the Hearing.

No. 26.—**P. H. LEDEBOER**—Deprez-d'Arsonval Dead-beat Galvanometer. **C. DECHARME**—Magnetic Images. **E. DIEUDONNÉ**—New Form of Electric Motor.

Vol. 21, No. 27.—**C. DECHARME**—Magnetic Images. **J. WETZLER**—Latest Experiments of Professor Bell on the Radiophone and Phonograph

No. 29.—**A. PALAZ**—Experiments on the Specific Inductive Capacity of some Dielectrics.

No. 30.—**C. DECHARME**—Magnetic Images. **A. PALAZ**—Experiments on the Specific Inductive Capacity of some Dielectrics. **J. ZACHARIAS**—Electricity as Motive Power for Tramways. **J. WETZLER**—New Apparatus for Registering Speech. **J. WETZLER**—New Vibrating Siphon Recorder for Atlantic Cables.

No. 31.—**L. PALMIERI**—Is the Electricity of the Earth Inductive or Induced? **A. PALAZ**—Experiments on the Specific Inductive Capacity of some Dielectrics. **G. BELLE**—A New Annunciator for Central Exchanges. **G. RICHARD**—Electric Railways and Tramways.

No. 32.—**G. RICHARD**—Details of Construction of Dynamo Machines. **C. DECHARME**—Magnetic Images. **A. PALAZ**—Experiments on the Specific Inductive Capacity of some Dielectrics.

No. 33.—**G. RICHARD**—Telephones. **C. DECHARME**—Magnetic Images. **J. WETZLER**—Underground Conduits for Wires in New York.

No. 34.—**L. PALIMIERI**—Variations of Atmospheric Electric with Altitude. **E. DIEUDONNÉ**—Central Electric Light Station at St. Etienne. **BERSON**—Influence of Temperature on Magnetisation.

No. 35.—**P. H. LEDEBOER**—Magnetic Field and Characteristic of the Gramme Machine. **G. RICHARD**—Electric Logs. **ESTIENNE**—

Telegraph System. **BERSON**—Influence of Temperature on Magnetisation.

No. 36.—**COSSMANN**—Applications of Electricity to Working Railway Signals. **ESTIENNE**—Telegraph System. **BERSON**—Influence of Temperature on Magnetisation.

No. 37.—**A. MINET**—Study of Galvanometers. **COSSMANN**—Applications of Electricity to the Working of Railway Signals. **C. DECHARME**—Magnetic Images. **J. WENZLER**—New Method of Telegraphing on Uninsulated Lines.

No. 38.—**J. LUVINI**—Conductivity of Gases and Vapours. **G. RICHARD**—Details of Construction of Glow Lamps. **COSSMANN**—Applications of Electricity to the Working of Railway Signals. **A. MINET**—Study of Galvanometers.

No. 39.—**G. RICHARD**—The Telephones. **C. DECHARME**—Magnetic Images. **A. MINET**—Study of Galvanometers. **B. MARINOVITCH**—A New Kind of Cable. **Dr. G. B. ERMACORA**—Unipolar Induction. **J. WENZLER**—A New Method of Regulating Clocks Electrically. Henry's Electric Locomotive. New Multiple Commutator for Telephony.

(*L'Electricien, Vol.* 10, 1886.)

No. 163.—**HOSPITALIER**—Conditions for Good Working of Arc Lamps. **GÉRARD**—Use of the Telephone for Testing Telegraph Lines.

No. 164.—**HOSPITALIER**—Intermittent Electric Light from Leclanché Batteries. **E. BOISTEL**—Law of Electro-Magnets. **R. ARNOUX**—Electrometer with Concentric Cylinders.

No. 166.—**HOSPITALIER**—Electric Lighting and High E.M.F. **E. BOISTEL**—Progress in the Theory of Dynamos (continuation).

No. 167.—**E. HOSPITALIER**—Automatic Switch for Charging Accumulators. **VASCHY**—Velocity of Electricity in a Straight-Wire.

No. 168—**HOSPITALIER**—Thermo-dynamic Potential and its Application to the Electric Phenomena. **G. ROUX**—Proper Size of Lead Wire for Safety Cut-outs.

No. 169.—**ZIPERNOWSKI**—Underground Conductors and High Potentials. **E. BOISTEL**—Progress in the Theory of Dynamos (continuation).

No. 170.—**E. HOSPITALIER**—Measurement of High E.M.F. **RADIGUET**—Temporary Lighter. *Anon.*—Universal Gauge for Wires.

No. 171.—**HOSPITALIER**—Photometry. **RAFFARD**—Dynamometer (Mechanical).

No. 172.—**HOSPITALIER**—Upward's Chlorine Battery. **De MERITENS**—Use of Electricity for rendering Iron Unoxidisable.

No. 173.—**HOSPITALIER**—Upward's Chlorine Battery. *Anon.*—Calibration of a Cardew's Voltmeter.

No. 174.—**HOSPITALIER**—New Method of Transforming Heat into Electricity. **G. ROUX**—Action of Solenoids on Iron Cores. **E. REYNIER**—Prevention of Buckling of Accumulator Plates.

No. 175.—**HOSPITALIER**—Transmission of Power between Creil and Paris, by M. Marcel Deprez.

No. 176.—**HOSPITALIER**—Measurements of the Power absorbed by Alternate-current Apparatus. **G. ROUX**—E.M.F. of Aluminium Cells.

No. 177.—**E. HOSPITALIER**—Calculation of the Dimensions of Continuous Current Dynamos. *Anon.*—Fischinger's Small Arc Lamp.

No. 178.—**L. BARADEL**—Telephonic Service between Paris and Reims over the Telegraph Wires. **A. GRAVIER**—The so-called Superiority of the Deprez Machine over the Gramme.

No. 179.—**E. HOSPITALIER**—Calculation of the Dimensions of Continuous Current Dynamos. **E. BOISTEL**—The Direction of Helices, right or left-handed. *Anon.*—Electric Soldering Apparatus.

No. 180.—**E. HOSPITALIER**—Calculation of the Dimensions of Continuous Current Machines.

(*Bulletin de la Société Internationale des Electriciens, Vol.* 3, 1886.)

No. 27.—**E. HOSPITALLIER**—Temporary Electric Lighting. **BOUDET DE PARIS**—Photographic Impression obtained inside Condensers. **PAUL SAMUEL**—Printing Telegraph of Mr. Munier.

No. 28.—**J. BOISSELOT**—Telephone with Movable Armature. **D. NAPOLI**—Duboulet's Regulator. **CORNELOUP**—Telephonic Call. **ESTIENNE**—System of Telegraphy.

No. 29.—**G. MARESCHAL**—Apparatus for working from a Distance Aboilard's Plunging Batteries. **A. DE MERITENS**—Iron and its Derivatives rendered Inoxidisable by the Electric Current. **SCOLA**—New Electric Fuses and Means of Testing them.

No. 30.—**A. CLAUDE**—System of Telegraphy. **A. BANDSEPT**—Electric Speed Indicator and Regulator. *Anon.*—Delany's Multiplex Telegraphy.

(*Journal Télégraphique de Berne, Vol.* 10, 1886.)

No. 5.—**A. FARJON**—Application of Bells to Hughes' Automatic Instruments working on Underground Lines.

Nos. 5-9.—**E. LANDRATH**—Working Telegraph Lines on Closed and on Open Circuit.

No. 7.—**NYSTRÖM and WENNMANN**—Automatic Distributor. **SACK**—Commutator for Intermediate Telephone Stations.

(*Annalen der Physik und Chemie, Vol.* 28, 1886.)

Part 2, No. 6.—**KUNDT and BLASIUS**—Researches on the Pyro-electricity of Crystals. **MACK**—Pyro-electricity of the Topaz. **STCHEGLAJEFF**—Electro-magnetic Rotation of the Plane of Polarisation of Light in Chloride of Iron. **HAGA**—Transference of Heat by the Electric Current. **HAUSEMANN**—New Method of determining the Time of Oscillation of Magnet Bars. **HIMSTEDT**—Reply to Lord Rayleigh's Remarks on any Determination of the Ohm.

Part 3, No. 7.—**HOPPE**—Theory of Unipolar Induction. **JAHN**—Equivalency of Chemical and of Current Energy. **JAHN**—Galvanic Polarisation. **ADLER**—Energy of Magnetic Polarised Bodies. **KOLÁČEK**—Gold Leaf Electroscope.

Part 4, No. 8.—**SOHNCKE**—Electrification of Ice by Friction of Water **DONLE**—Thermo-electric Properties of Electrolytes. **AUERBACH**—Conductivity of Metallic Powders. **KRÜGER**—New Method of determining the Vertical Intensity of a Magnetic Field.

Vol. 29, Part 1, No. 9.—**HALLWACHS**—Determination of Contact Differences of Potential without a Condenser, and Description of a New Form of Electrometer. **KOHLRAUSCH**—Simple Form of Local Variometer for determining the Horizontal Intensity of Earth's Magnetism. **SACK**—Specific Induction Constants of Magnets in Magnetic Fields of various Strengths.

(*Centralblatt für Elektrotechnik, Vol.* 8, 1886.)

No. 12.—**V. GAISBERG**—Experimental Tests of Dynamo Machines.

No. 13.—*Anon.*—Length of Useful Wire on Helices of Dynamos. **Dr. M. KRIEG**—New Formulæ for Electro-Magnetism, and their Practical Value.

No. 14.—*Anon.*—Weston's Current and Energy Meters. **J. KESSLER**—A Standard Instrument for Absolute Measurements. **A. VON OBERMAYER**—Magnetic Properties of Malleable Cast-Iron.

No. 15.—**V. GAISBERG**—Thomson's Bridge at the Physical Mechanical Institute of Dr. Edelmann. **J. KESSLER**—A Standard Instrument for Absolute Measurements. **EXNER**—Laws of Atmospheric Electricity.

No. 16.—**Dr. M. KRIEG**—Marcel Deprez's Theory of the Dynamo Machine. **C. H. WOLFF**—A New Form of Gas Voltameter.

No. 17.—*Anon.*—The Poege-Fischinger Small Arc Lamp. **Dr. M. KRIEG**—Marcel Deprez's Theory of the Dynamo Machine. **Dr. STRECKER**—Photometry in Practice, with Especial Reference to Incandescent Lamps.

No. 18.—**Dr. M. KRIEG**—Marcel Deprez's Theory of the Dynamo Machine. **Dr. STRECKER**—Photometry in Practice, with especial Reference to Incandescent Lamps. **P. SEUBEL**—A Practical Use of the Microphone·

No. 19.—**A. ROITI**—Comparison of the Electro-Calorimeter with Reiss's Thermometer. **G. BETZ**—Paraboloid Mirror for Electric Lamps.

No. 20.—*Anon.*—Lobbecke's Block System for Railways. **R. HEGELMANN**—Construction of Lightning Conductors. *Anon.*—Portable Electric Light Apparatus.

No. 21.—*Anon.*—Fusible Cut-outs.

No. 22.—**Dr. M. KRIEG**—Marcel Deprez's Theory of Dynamo Machines.

No. 23.—**Dr. V. WIETLISBACH**—Self-Induction in Straight Wires. **Dr. M. KRIEG**—Marcel Deprez's Theory of the Dynamo Machine.

No. 24.—*Anon.*—Improved Form of D'Arsonval's Galvanometer. **Dr. H. SACK**—Specific Induction Constants of Magnets in Magnetic Fields of

various Intensities. **Dr. M. KRIEG**—Marcel Deprez's Theory of the Dynamo Machine. **K. ZICKLER**—Calibration of a Cardew Voltmeter. **PEUKERT and ZICKLER**—Efficiency of Zipernowski Deri Transformers. **UPPENBORN**—Iron Guard Ring for Mirror Galvanometers.

No. 25.—**Dr. B. NEBEL**—Two Methods for measuring the E.M.F. of the Electric Arc. **K. ZICKLER**—Magnetisation Curves of Iron and Steel as a Measure of their Hardness.

(*Elektrotechnische Zeitschrift*, 1886.)

June.—**FRISCHEN**—Improvements in the Manufacture of Cables. **Dr. T. BRUGER**—Action of Solenoids on variously-shaped Cores. **G. WABNER**—Working of Long Underground Lines. **Prof. Dr. G. HOFFMANN**—Mercadier's Theory of the Telephone.

July.—**W. KOHLRAUSCH** — A Convenient Method of measuring the Strength of a Current and its E.M F. with a Mirror Galvanometer, and its Use for the Calibration of Working Instruments. **Dr. G. STERN**—Frölich's Current Curve. **Dr. E. HOPPE**—Unipolar Induction. **M. HOLST**—Translation between Two Closed Circuits. **L. KOHLFURST**—Dr. Siegfried Taussig's Safety Telegraph. **L. WEBER**—Leupold's Electric Current Measurer for Direction and Speed.

August.—**R. von FISCHER TREUENFELD**—Military Telegraphs in Sweden. **E. ZETSCHE**—Adt's Electrical Watchman's Detector.

September.—*Anon*—Electrically-controlled Clocks. **Dr. B. WEINSTEIN**—Earth Currents (continuation).

(*Zeitschrift für Elektrotechnik*, 1886.)

May. — **Dr. J. STEFAN** — The Characteristic of an Alternate-current Machine. **MAX JULLIG**—Determination of the Intensity of Periodical Varying Electric Currents. **M. BURSTYN**—Electric Fuses. **W. PEUKERT**—The Transformation of Heat into Electrical Energy. **Dr. O. TUMLIRZ** — The Lightning-Rod System of Melsens. *Anon.*—McCulloch's Fire and Telegraph System.

June.—**C. ZICKLER**—Magnetisation Curve of various kinds of Iron and Steel, and a Method of thereby determining their Hardness. **Dr. A. von WALTENHOFEN**—Remarks on the above Article. **O. VOLKMER**—Photography of Lightning. **W. PEUKERT**—The Transformation of Heat into Electrical Energy. **Dr. RUDOLF LEWANDOWSKI**—Improvements in Induction Apparatus. **A. E. GRANFELD**—The Aurora of 30th March. **Dr. E. KAMMERER**—The Sanitary Aspect of Gas in Comparison with the Electric Light. **Dr. O. TUMLIRZ**—The Lightning-Rod System of Melsens. **F. v. BECKER**—Management of Leclanché Batteries.

July.—**K. ZICKLER**—Calibration of a Cardew Voltmeter. **J. KOELZER** — Translation System for Open and Closed Circuits. **Von DZIESLEWSKI**—The most probable Relation between the whole Electrical

Work and the Light of a Glow Lamp. **W. MISCA**—Parallel Grouping of Relay Coils on Closed Circuits. **Dr. E. KAMMERER**—The Sanitary Aspect of Gas in Comparison with the Electric Light. *Anon.*—Electric Transmission of Power at Uster.

August.—**E. GERARD**—Self-Induction in Electric Conductors. **J. KROST**—Electric Light Installation on the Sophia Island. *Anon.*—Experiments with Meyer's Multiplex Apparatus as Intermediate Instrument. **H. SACK**—Specific Induction Coefficients of Hard Annealed Steel Bars. **J. KOLBE**—Magnetic Lines of Force. **C. GRAWINKEL**—Use of Dynamos instead of Batteries on Telegraph Lines.

September.—**W. PEUKERT**—The Mean Intensity of the Magnetic Field of Dynamo Machines in Absolute Measure. **Dr. A. KLEINER and Prof. R. HOFMEISTER**—The Illuminating Power and Work absorbed by Glow Lamps. **H. SACK**—Specific Induction Coefficients of Hard Annealed Steel Bars. **E. FODOR**—Automatic Copying Telegraph for Newspapers. **A. BERNSTEIN**—New Process for making Filaments of Glow Lamps. **J. KESSLER**—Standard Instrument for Absolute Measurements. *Anon.*—The Working of Ordinary Batteries in Telegraphy.

INDEX TO VOL. XV.

1886.

ABSTRACTS.